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PRELIMINARY OBSERVATIONS ON THE NOSE OF THE AUSTRALIAN ABORIGINAL, WITH A TABLE OF ABORIGINAL HEAD MEASUREMENTS

By A. N. BURKITT, M.B., B.Sc., *Lecturer in Anatomy,*
AND
G. H. S. LIGHTOLLER, M.B., Ch.M., *Honorary Demonstrator in Anatomy, University of Sydney.*

These observations are based upon (1) an examination of the bony nose in the aboriginal skulls in the Anatomy Department and in the Museum of Morbid and Normal Anatomy of the University of Sydney and the Roth series of aboriginal skulls in the Australian Museum together with various other European, South African negro, and Melanesian skulls, and (2) examination and dissection of the nose in two aboriginal heads. So far only one head (H. B. 1) has been dissected in full detail, but it is apparently a fairly typical specimen of the Australian aboriginal as regards the general features (see fig. 1).

With regard to the nose of H. B. 1, while its external features are typical, the bony nose deviates in one respect: the apertura piriformis is amblycraspedote, whereas most of the aboriginal skulls in our possession are bothrocraspedote or orygmocraspedote; otherwise the features are typical[1].

The spine is only moderately projecting, thus bringing this skull into the lophacanthic group[2].

As is commonly found in our series of skulls, the nasal bones present the typical depressed form, and the nose is platyrrhine.

At the end of this article is a table of anthropometric measurements of the two heads and of soft tissue thickness measurements for reconstruction work (Table A) together with definitions of the points used.

All the general data (e.g. skull measurements) are necessarily incomplete with the exception of the nose, as these observations are intended to be preliminary to a complete description of the facial muscles and other features of the two heads.

EXTERNAL NOSE

As regards the external nose, the various measurements are to be found in Table A.

A clear idea of the nose may be obtained from the accompanying figures,

[1] Macalister (13) distinguishes four types of aperturae: (*a*) oxycraspedote or European type with the sharp lower margin; (*b*) bothrocraspedote, with well developed fossa praenasalis; (*c*) amblycraspedote, a type intermediate between these two; (*d*) orygmocraspedote, the anthropoid type with a smooth lower margin.

[2] Macalister in the same article distinguishes three types of nasal spine: (*a*) oxyacanthic, in which the spine is well developed (European type); (*b*) cryptacanthic, where the spine is rudimentary or absent; (*c*) lophacanthic, where the spine is intermediate between the above two

and accurate casts of the heads are preserved in the Anatomy Department, Medical School of Sydney University for future reference. These casts were made of printers' roller composition, a very elastic and durable material, giving perfect moulds of such structures as the ears, which are very difficult to obtain with plaster of Paris.

The aboriginal nose is remarkable for three things:

(i) The absence of any true tip to the nose, there being a convex ellipsoidal area instead of a true tip or point.

In the absence of a tip to the nose as a point from which to measure, an arbitrary tip was obtained in the following way: The curved alar margins of the nostrils (i.e. the medial edges of the alae) were continued medially in their

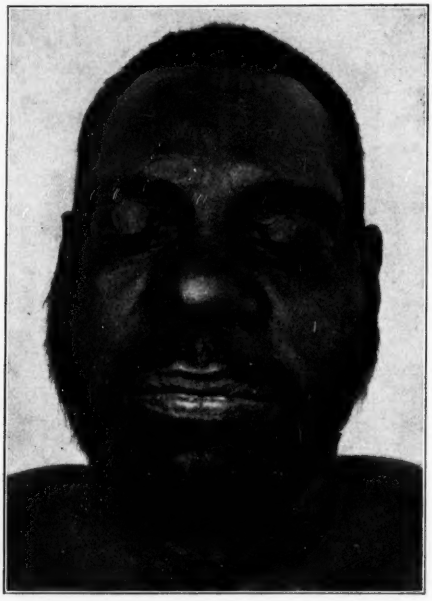

Fig. 1. Norma facialis of H. B. 1. (Photo.)
(All figures unless otherwise indicated are oriented in the Frankfort horizontal plane.)

curve until they met in the middle line. This medial point was found to be almost the most projecting point, and in these aboriginals was called the tip of the nose.

(ii) The great width and small height of the lower portion of the nose, i.e. that portion below the bridge. The nostril is remarkable for its wide lateral extent, so wide that the ala nasi lies completely lateral to the bony apertura piriformis, and also for the fact that it is possible to inspect directly the floor

of the nasal cavity through the anterior nares with scarcely any manipulation of the ala nasi.

Another feature brought out on dissection was the great development of the pars transversa of the m. nasalis and its probable moulding effect on the nose contour. This is indicated in fig. 3, where it will be seen that the skin thickens just below the rhinion, this being due to the great thickness of this muscle, which unites with its fellow of the opposite side to form a broad flat sheet of muscle over the cartilaginous dorsum of the nose.

(iii) The depressed bridge of the nose—this flattened appearance is due in part to the small and depressed nasal bones, but is accentuated by the broad fold of skin covering the musculus oculo-buccalis[1], and the pad of fat in the areas extending from the bridge of the nose to the cheek and hereafter referred to as the naso-buccal gyrus. This gyrus seems to be a pronounced feature in the aboriginal and makes the bridge of the nose seem to be almost on the same plane as the face.

This type of nose is commonly seen in newly born white infants in which all three peculiarities are well marked.

THE MUSCULATURE OF THE NOSE

The nomenclature used by Eisler(7) has been followed.

The chief features observed in H. B. 1 were: (1) the great size and thickness of the m. nasalis both in its pars transversa and pars alaris; (2) the large and well formed m. alaris nasi. This arose mainly from the whole outer surface of the lateral crus of the cartilago alaris major and formed a continuous sheet of muscle (Henle, Eisler, Schwalbe). This sheet of muscle represents the anterior and posterior dilator muscles of Cunningham. (3) The wide lateral extent of the depressor septi portion of the orbicularis oris (see Poirier(14)). (4) The presence of definite anomalus maxillae muscles on both sides of the face. (5) We suggest that the musculature forms a nearly complete constrictor of the nose aperture not at the nostril, but laterally at the junction between the vestibule and the true nose cavity.

This "orbicularis nasi" (see, however, Eisler, pp. 145, 146) was further confirmed by tracing the relation of the edge of the bony aperture to the cartilaginous and movable framework of the nose, when it was found that the pars transversa followed closely the junction between the bony and movable portions of the nose. No trace of a musculus apicis nasi could be found.

MOVABLE FRAMEWORK OF THE NOSE

Turning now to the alar cartilages, septum, etc.

(1) The *cartilago alaris major* agrees with that of the American negro, in that the lateral crus does not run parallel with the medial as in most Europeans, but is bent up at a marked angle (fig. 3). This angle seems to be even

[1] The oculo-buccal muscle is a special development of fibres from the orbicularis oculi and extends down from the inner canthus to be inserted into the fat and skin of the cheek.

more marked than in the negro, judging by Schultz's figures (15). Kallius (10), however, figures (p. 126, fig. 7) a squat female European nose in which the two crura form an angle. It is evident from fig. 2, that the lateral crus of the greater alar cartilage takes little or no share in the support of the ala nasi, but acts as a basis of support for the m. alaris nasi.

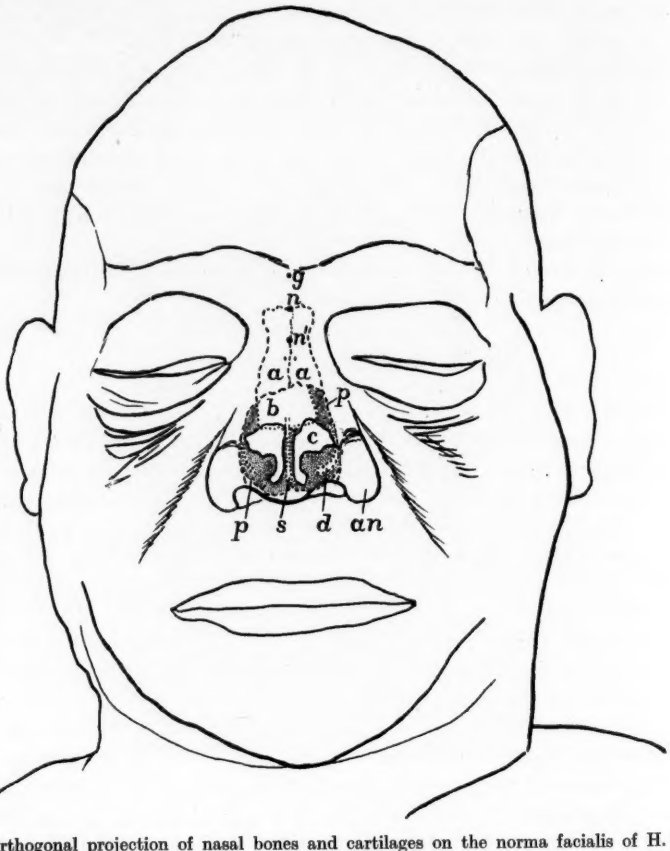

Fig. 2. Orthogonal projection of nasal bones and cartilages on the norma facialis of H. B. 1. *a.* Ossa nasalia; *b.* cartilago nasi lateralis; *c.* cartilago alaris major; *d.* cartilago alaris minor; *g.* glabella; *n.* nasion; n^1. pseudonasion; *an.* ala nasi; *s.* cartilago septi nasi; *p.* margin of apertura piriformis.

Another very definite feature was the marked way in which the upper borders of this cartilage overlapped the lateral cartilage (figs. 2 and 3), an indication probably of the large size and mobility of the soft parts of the nose and of the anterior direction of the nostril. This, however, is seen in the white race (see Kallius, figs. 4, 6 and 7). Although the larger alar cartilages project

well beyond the septum nasi, as is the case in most negroes (fig. 3), yet we doubt if they were in contact, though possibly, as the result of dissection, we may have separated them to a greater extent than was actually the case in the living subject (fig. 2). The hinder pointed extremity of the lateral crus was 3 mm. anterior to the margin of the apertura piriformis on the right side and 4 mm. on the left side.

(2) The *lateral cartilages*, which are really expansions of the septal cartilage, approximate more closely to the quadrangular shape believed by Schultz to be characteristic of the white races (figs. 2 and 3).

(3) Nothing can be stated definitely regarding the frequency of the minor alar cartilages and the sesamoid cartilages (see figs. 2 and 3).

(4) As regards the *septal cartilage*, it will be seen from fig. 3 that it follows fairly accurately the contour of the nasal bones as far as the lower edge of the lateral expansions, and that immediately below this, it commences to curve downwards and backwards. The general outline of this cartilage is very similar to that figured for the negro by Schultz.

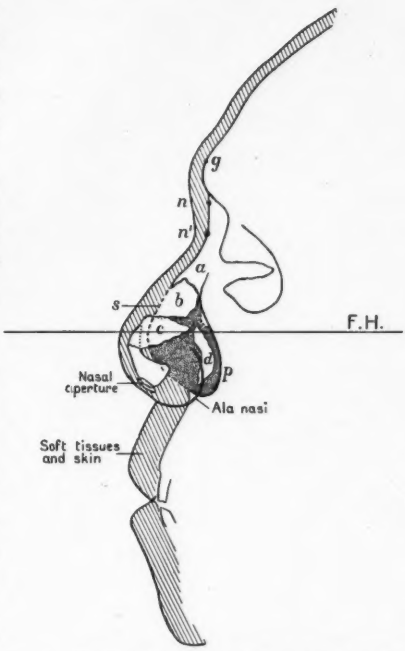

Fig. 3. Profile view of nasal framework and of external nose in H. B. 1. (Lettering as in fig. 2.)

THE RELATION OF THE EXTERNAL NOSE TO ITS BONY AND CARTILAGINOUS FRAMEWORK

The profile of the nose follows that of the nasal bones fairly closely, but over the septum nasi we see the soft tissues thicken owing to the great development of the pars transversa of the m. nasalis, whereas the procerus muscle in H. B. 1 seemed to have little direct effect in altering the contour over the nasal bones. The thickness of the soft tissues (see fig. 3) at the tip of the nose and at the nasal spine (·8 cm.) also exceeds the average found in white and negro (Schultz).

It is also immediately apparent from figs. 2 and 3, that the ala nasi lies almost completely lateral to the bony apertura piriformis and that its hinder border is a few millimetres anterior to the bony apertura in profile view. These facts are of value for reconstruction purposes. These figures also show that the nostril lies at the level of the lower bony margin of the aperture, and both in

the living and the dead aboriginal, it is a commonplace observation that the floor of the nose can be inspected through the anterior nares with scarcely any manipulation of the soft tissues of the vestibule, this condition being quite the reverse of the average white nose.

Schultz, in discussing the relation of the breadth of external nose to the breadth of the apertura piriformis, expressed the relation by an index,

$$\frac{\text{Breadth of aperture} \times 100}{\text{Breadth of nose}}.$$

This gives H. B. 1 an index of 62·4, slightly below the average found in the negro (Schultz).

Schultz says that "no conclusions concerning the breadth of the external nose can be drawn from the breadth of the bony aperture." He found even in the adult negro that the index varied from 53·2 to 78·9.

From an examination of photographs and of actual living aboriginals, we are of opinion that the index will be found to be always low and to vary to a much less degree than in white and negro noses. This is confirmed by Klaatsch (p. 70). As a result of this great width, we believe that the alae nasi will be found to lie very constantly lateral to the bony aperture.

AREA PRAENASALIS

As regards the bony apertura piriformis, we have little to add to the accurate descriptions of Macalister and Klaatsch. We had concluded a preliminary survey of a large number of Australian aboriginal and other skulls before we discovered Macalister's work. Our efforts were directed towards arriving at a satisfactory interpretation of the wide range of variation found more especially at the lower border of the apertura, from the smooth gutter-like anthropoid condition to the sharp knife-like margin found in the average European skull.

Macalister divides the bony margin of the apertura in the foetal European skull into four portions:

(1) The nasal bone edge; (2) the sharp lateral edge of the frontal process of the maxilla; (3) a smooth intermediate area; (4) the paraseptal line. These he traces in the adult skulls of various races. Looking at the skull in the lowest types, he recognised that the alveolar bone of the large prognathous incisor teeth in these races, rounded off the intermediate area and converted it into a smooth gutter leading from the nose on to the face, while at the same time the nasal spine was less developed and almost absent. He further recognised that in skulls of races somewhat higher in the scale, the intermediate area was converted into a pit or fossa, bounded posteriorly by the *paraseptal ridge* and a lateral continuation of it, which he called the *anterior dental ridge*.

This latter ridge runs to the lateral wall of the nose, near the inferior turbinate at its anterior end. It is often seen to be channelled and to contain the anterior superior alveolar nerves and vessels to the incisor teeth. Klaatsch called these combined ridges the *margo infranasalis*. Bounding this pit

anteriorly is another ridge which was not apparently named by Macalister, but which Klaatsch called the *crista praenasalis*.

We have used the following descriptive terms:

(1) *Margo infranasalis* formed by (*a*) *Anterior dental ridge*, (*b*) *Paraseptal ridge*.

(2) *Crista praenasalis* (or incisor ridge).

(3) *Area praenasalis*, which lies between (1) and (2) and is approximately the same as the fossa praenasalis or Macalister's intermediate area.

The term area is used, instead of fossa, as there are many orygmocraspedote (gutter-like) skulls, in which the ridges are so rudimentary that the area, while still distinct, becomes smooth and does not form a fossa. In aboriginal skulls, we find that the smooth gutter-like type of the apertura predominates; next comes a type in which the ridges are present, but the fossa is ill developed; finally we find the types with well-marked ridges and a true fossa. This latter bothrocraspedote form, is not so common as we had at first thought. Amblycraspedote skulls are very occasionally to be found.

The next feature we wish to emphasise is the remarkable variability of the above-mentioned ridges in aboriginal skulls. This was also remarked upon by Klaatsch. Thus we find skulls with the paraseptal ridges present or absent. Similarly with the anterior dental ridges and the cristae praenasales. The most constant ridges were the paraseptal ridges, next in frequency were the anterior dental ridges and the cristae praenasales in their lateral portions. In the aboriginal skulls available to us, we find the ridges completely absent, more especially (1) in young skulls up to 16–18 years of age, provided the alveolar prognathism is marked (example: Mus. N. and M. A., No. 1311) and (2) in many old skulls (as indicated by tooth-wear) (e.g. Mus. N. and M. A., No. 1308).

These cases are usually associated with a poorly developed nasal spine. Further we would remark upon the close approximation of the teeth to the nasal aperture, so that the average distance from the tips of the roots of the mesial incisor teeth, to the centre point of the medial end of the area praenasalis is only about 3 mm. This is a remarkably constant feature of a series of aboriginal skulls and has been partly emphasised by Klaatsch. In many skulls, the central incisor tooth of one side is missing and the alveolus partly absorbed, the tooth having been knocked out at puberty, in initiation ceremonies. In these skulls, on the side of the missing tooth only, the crista is less well-developed, and in closer apposition to the margo infranasalis, thus narrowing the area praenasalis and causing it to approximate to the condition seen in the amblycraspedote skull. We may remark here on a variation, seen by us in one Australian aboriginal skull, one Melanesian, and three African negro skulls. In these skulls, in spite of a considerable degree of alveolar prognathism (see fig. 4), the area praenasalis was apparently absent and the entrance to the nose was guarded by a fairly sharp margin, representing, we believe, the margo infranasalis. This margin, however, never became as sharp as that found in the typical oxycraspedote skull. Another African negro skull

in the Australian Museum approximated very closely to this condition (Aus. M., No. 1211). Now in all these skulls, we found that the distance from the tips of the roots of the incisor teeth to the margo infranasalis was very considerable (12–15 mm.). The significance of this will become apparent later.

Turning now to the influence of the softer tissues on the bone, from dissections of H. B. 1, we doubt if the depressor portion of the m. nasalis (called by Eisler the pars alaris) plays any part in the formation of the crista praenasalis. In examining the relation of the fossa or area praenasalis to the soft parts of the nose it was found that, approximately, the posterior wall of the vestibule was bound down to the area praenasalis by tough fibrous tissue. This has been confirmed by a histological examination of this tissue, when it was found not to be markedly vascular and to contain much fibrous tissue and fibro-cartilage.

INTERPRETATION OF THE VARIATIONS FOUND IN THE BONY APERTURA IN MAN AND ANTHROPOIDS

We believe that the variations found in this region of the bony nose, may all be interpreted as follows: The main factors moulding the bone are—

(1) The degree of alveolar prognathism with which may be coupled the amount of arching or curvature of the teeth. Thus we find some skulls with a marked arching of the bone from the nose to the alveolar margin, while in others which present marked alveolar prognathism the bone is yet fairly flat and straight, and the teeth are straight from biting edge to root apex.

(2) The second factor influencing the lower margin of the apertura is the distance from the tips of the incisor tooth roots to the margin of the apertura, or more accurately to the medial end of the chief diagonal of the oval praenasal area or fossa.

(3) The size of the teeth, their "set" or direction, and, of course, the pressure of the bite on them and its frequency of application. (These last factors are obviously almost incalculable at present.)

Correlated with the above factors is the arching or flattening of the anterior portion of the palate. In prognathous skulls, if the roots of the incisor teeth lie close to the lower margin of the apertura piriformis, the anterior portion of the palate is flattened but if the roots of the incisor teeth lie at a distance from the lower margin of the apertura piriformis, the anterior portion of the palate is arched.

In orthognathous skulls the anterior portion of the palate is arched, although the roots of the incisor teeth lie close up to the lower margin of the apertura piriformis.

(4) The shape and size of the vestibule of the nose, the posterior wall of which is adherent to the area praenasalis. We may call this the respiratory factor, and it is at present incalculable.

The influence of these factors may be outlined in the case of the crista praenasalis. The crista praenasalis is only developed in those skulls in which

the teeth, though prognathous, are less so than in orygmocraspedote skulls. At the same time the teeth must lie close up to the nose, or they must be so large and powerful that their pressure influences the lower margin of the apertura piriformis. Further evidence in favour of the cristae being closely correlated with pressure effects of the incisor teeth, is to be found in their absence in young aboriginal skulls, and in very old skulls. Again we see the reduction of the crista on one side in skulls where the tooth of that side has been knocked out at puberty. Again we have their reduction or complete absence in the exceptional skulls which have been mentioned above, e.g. those in which the distance from the tips of the incisor teeth to the nose aperture is over 1 cm. In these cases the large mass of bone between the teeth and the nose obviates the necessity for the development of a strut or crista praenasalis. If, however, in these latter cases the teeth are very large and powerful, we may get a condition approximating to the orygmocraspedote skull, but with a fairly well-developed nasal spine, large paraseptal ridges and the crista while developed laterally, fades away medially. This is the condition found, we believe, in *Homo Rhodesiensis*. It needs a somewhat less degree of prognathism of the incisor teeth, to produce the sharp margin found in Neanderthal man, resulting from the approximation of the paraseptal ridge to the lateral remnant of the crista praenasalis.

We may mention here a further observation, namely that while usually the medial incisors have their long axes slightly divergent as they approach the nose, occasionally we find their axes directed somewhat medially. An example of the latter condition is R 25 (Aus. Mus.) and in this particular skull we find an unusual degree of prominence of the nasal spine and the paraseptal ridges.

We may finally observe that the crista may often be traced from the tip of the root of the median incisor to the lateral margin of the apertura. Moreover, it may be observed to be reinforced by the lateral incisor root and more laterally still by the canines.

On the basis of the above observations, we believe that a regular series of skulls may be traced from the anthropoid to the European, exhibiting a complete correlation between the above-mentioned factors and the shape of the lower margin of the apertura piriformis. First in the anthropoid skull, the incisor teeth are large, curved and prognathous, and relative to their size close up to the apertura of the nose. The anterior part of the palate is also flat. The set of their roots is also distinctly lateral. In these cases, the bone supporting the incisor teeth becomes rounded off at the apertura, curving laterally into a solid rounded pillar at the side of the apertura. This rounding of the bone at the side of the apertura is further correlated with the large canines, especially in the adult anthropoid. Meanwhile, the taking up of the thrust of these teeth, in part horizontally by the palate and in part laterally by the solid pillar of bone at the lateral margin of the apertura, obviates any need for the septum to play any very active part in the support of the teeth. Hence the nasal spine is small or absent.

Next we come to the similar type found in aboriginal skulls, which however differs in that the teeth are now reduced, less prognathous and probably their long axes less divergent. Nevertheless the teeth are still large, prognathous, curved and close up to the nose, while the palate is flattened, i.e., not arched. In these a nasal spine commences to develop to help in taking up the more vertical thrust of the incisors. Actually we find in these orygmocraspedote aboriginal skulls, that the spine is never absent, though usually very poorly developed. Further, in these same skulls the canine teeth have undergone reduction and the lateral margin of the apertura is consequently much sharper than in the anthropoid, though frequently showing some degree of rounding off, especially at its base.

Turning to the next stage, we find that the teeth become less prognathous, less curved, but still remain close up to the nose, thus their thrust becomes still more vertical and consequently we get a strut of bone developing, viz., the crista praenasalis. Further the nasal spine becomes more projecting. The anterior part of the palate is still flattened. This gives us the bothrocraspedote skull with a fossa praenasalis. We may remark that in the bothrocraspedote skull, the margo infranasalis also becomes more defined, but while its paraseptal portion is probably related to tooth pressure, the anterior dental portion may or may not be.

The next in the series is the amblycraspedote type in which the teeth, though apparently of much the same size, become still less curved and less prognathous, while remaining close up to the nose. Hence their thrust is delivered still more vertically. In these skulls the area praenasalis becomes narrowed and partly thrust on to the face; the crista praenasalis and the margo infranasalis become approximated, the crista developing only laterally, while the paraseptal ridge become accentuated medially, with the narrow area praenasalis lying obliquely between them. At the same time, the nasal spine becomes more projecting, while the palate anteriorly now shows a modern degree of arching.

Finally, we come to the oxycraspedote condition, in which the teeth, whether large or small, are straight and disposed almost vertically, and may be close up to or distant from the nose. In these the crista praenasalis disappears medially, but its lateral portion fusing with the paraseptal ridge, forms a sharp margin separating nasal cavity from alveolar bone of the face, and the nasal spine is markedly projecting. It is probable that we may best interpret this condition as one in which the praenasal area has been thrust forward on to the face. At the same time the palate becomes well arched. The above theory gives a broad outline of what we consider to be the general trend of evolution of this region and assumes that the main factors concerned are the teeth (as regards size, curvature, and degree of alveolar prognathism, together with their distance from the nasal aperture). Deviations, when they occur, may be correlated with variations in the factors previously named, and of these two may be specially mentioned.

(*a*) The first case is that in which the tips of the incisor teeth are widely separated from the nose (1 cm. or more). In such cases, if the teeth are very large and markedly prognathous, the ordinary orygmocraspedote skull character may obtain (Aus. Mus. B 3715 and B 1178). The Talgai skull belongs to this group, as the incisor teeth were very large and markedly prognathous, and the distance of the central incisor root apices from the lower margin of the apertura piriformis is certainly not less than 1·0 cm. In other of these cases, we find the teeth are either smaller or the prognathism is slightly less marked. In these the teeth are so widely separated from the margo infranasalis, that there is a thick

Fig. 4. Photo of skull of African negro (A. D. No. 232). Oblique view to illustrate unusual type of Apertura piriformis, as regards its lower edge.

mass of bone supporting them before ever the nasal aperture is reached. At the same time the floor of the nose seems to be tilted backwards to such an extent that the alveolus, in spite of its prognathism, really meets the floor of the nose nearly at a right angle. Hence the medial portion of the crista praenasalis does not develop, and the result is a type somewhat resembling the oxycraspedote skull, with a blunt angulation of the edge of the apertura piriformis (fig. 4).

From the imperfect casts and data at our disposal it would seem that an accentuation of this condition is seen in *Homo Neanderthalensis* (Smith Woodward (17)).

(*b*) The second deviation is that mentioned by Klaatsch. In this case, the fossa praenasalis, instead of lying obliquely at a slope intermediate between that of the floor of the nasal cavity and the alveolar bone of the incisor teeth, has been so tilted upwards as to lie parallel with the floor of the nose and almost inside the nasal cavity; further the crista has been converted into the apparent margin of the apertura, but the margo infranasalis can be plainly seen inside the apertura, limiting posteriorly what is undoubtedly the fossa praenasalis. The fossa praenasalis therefore lies practically on the floor of the nasal cavity.

The probable explanation of this condition is that the teeth, while on the one hand disposed much more vertically than usual, nevertheless, lie considerably in advance of the nose, and hence the fossa praenasalis, instead of lying obliquely as in the ordinary bothrocraspedote skull, has been tilted up anteriorly, and so lies in line with the floor of the nasal cavity.

REMARKS UPON THE SHAPE OF THE SEPTAL CARTILAGE AND OF THE APERTURA PIRIFORMIS

In the previous section, we have outlined an hypothesis in which certain factors influence the bony area praenasalis. We believe that the same factors are probably active in moulding the shape of the septal cartilage and even of the apertura piriformis itself.

(*a*) *The septal cartilage.* Macalister realised this clearly when he stated that the projection of the nose and nasal septum, in the white races especially, is a negative feature, due to retraction of the incisors and canines, i.e., to orthognathism. Schultz(15) shows this in his fig. 4, p. 337.

We would suggest that, besides this passive factor in causing prominence of the nose in white races, there is a very active factor. If we examine the upward thrust of the incisor teeth in an orthognathic skull, it will be seen that this thrust, so far as it affects the septum, will tend to squeeze it out anteroposteriorly and thus tend still further to accentuate the tip of the nasal septum. At the same time the septum has probably more direct pressure to bear (at least anteriorly) in the orthognathic than in the prognathic skull (see figs. 5 and 6).

(*b*) These factors probably also mould the shape of the apertura piriformis to some extent. Schultz found that in the growth of the nose from infancy to adult life, the breadth of the bony apertura increases at a greater rate than the external nasal breadth, whereas the bony and external nasal height measurements showed the opposite relation, the bony apertura growing less in a vertical direction than the soft parts. These facts would receive a simple explanation on the hypothesis that the pressure of the incisor teeth influences the growth of the bony apertura, squeezing it more than the soft parts of the nose.

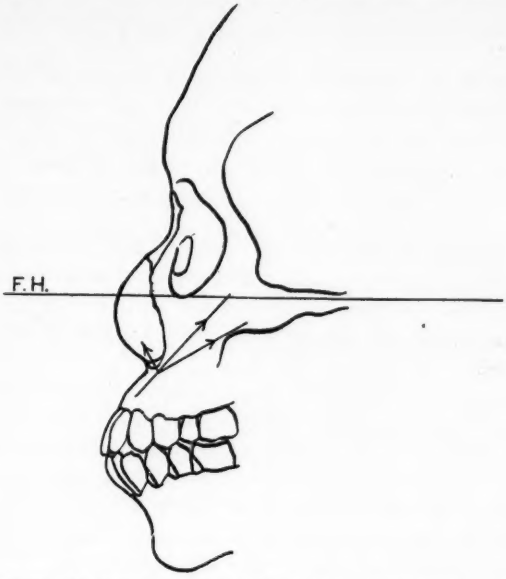

Fig. 5. Sketch suggesting the influence of the incisor teeth on the septum nasi in a prognathous Australian aboriginal.

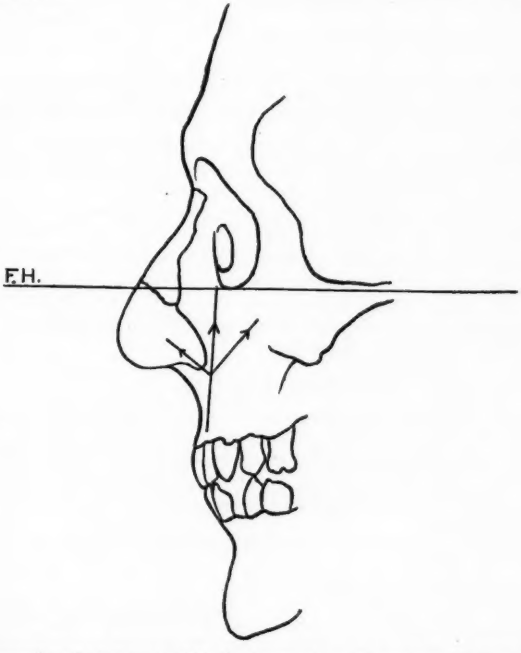

Fig. 6. Sketch suggesting the influence of the incisor teeth on the septum nasi in an orthognathous European.

SUMMARY AND CONCLUSIONS

(1) The nose in the Australian aboriginal is very broad and flat, and its cartilages correspond very closely to those of the negro in shape.

(2) The ala nasi probably lies altogether lateral to the bony apertura.

(3) In the aboriginal the skull tends to be orygmocraspedote, and has well-developed praenasal areas, with the incisor teeth closely approximated to the nose.

(4) That in all skulls observed by us, whether of anthropoid apes, fossil type of man, of aboriginal, negroes, Melanesian or white type of man, the variations to be seen in the area praenasalis, and the lower margin of the apertura piriformis, are due chiefly to the tooth pressure of the upper incisor and canine teeth.

(5) That to estimate the tooth pressure, one must take into consideration both the force, the frequency and mode of application of the bite, and the size, curvature and age of the teeth, the direction of their axes and the approximation of their apices and the margin of the apertura piriformis.

In conclusion, we wish to thank Mr Louis Schaeffer, of the Anatomy Department, University of Sydney, for help in preparing the figures, and also the Director and officers of the Australian Museum, Sydney, for their help and courtesy; we also thank the Acting-Professor of Anatomy, Dr Maguire, for the use of laboratories and material.

TABLE A

Anthropometric Measurements of the Heads of two Australian Aborigines (with Definition of Terms and Table of Skin and Soft Tissue Thicknesses.)

The terms and abbreviations used have been largely taken from Wilder (16).

In measuring skin and soft tissue thicknesses, a needle has been inserted as nearly as possible at right angles to the facial skin contour at the point measured.

We have retained the anthropometric abbreviations where measurements of skin thickness were made over corresponding points. The two heads are called H. B. 1 and D. B. 2. Of them H. B. 1 was injected with formalin (10 per cent.) and was slightly shrunken in the scalp region. D. B. 2 was prepared with the usual dissecting-room injection formula (glycerine, 12 parts, arsenic, 1 part, heat gently to boiling point. Take 1000 c.c. of the mixture, 1000 c.c. of carbolic acid, 1000 c.c. of methylated spirit, and 1000 c.c. of 20 per cent. formalin; well mixed and shaken) and was fairly normal.

Definition of Terms.

c. Commissural point. The point where a line joining the two medial palpebral commissures crosses the mid-line.

eap. The most prominent point on the external angular process of the frontal bone.

g^1. A point 1 cm. lateral to the glabella in the same horizontal plane.

go^1. A point at the lower and outer border of the mandible midway between the edges of the masseter.

go^2. A point on the lower and outer border of the mandible immediately anterior to the masseter muscle.

ii. The lowest point in the incisura intertragica.

im. Malar point. The point of intersection of a vertical line through the ectoconchion (Wilder) and a horizontal line through the lowest point of the bony orbital margin. Roughly the most prominent point of the malar bone, but defined as above owing to the difficulty of determining the most prominent point in H. B. 1.

inf. Maximum depth of the infraorbital fossa between *ior.* and a horizontal line passing through the subnasale.

ior. The centre point of the inferior orbital margin.

la. The point where the lower edge of the ala nasi meets the skin of the upper lip.

lcl. The lachrymal point. The point of junction of a horizontal line through *ior.* and the outer line or margin of the external nose.

ms^1. The most lateral point of the mastoid process.

n^1. Pseudonasion. The most depressed point in the nasal profile.

$\frac{n^1.\text{–}rh.}{2}$ The midpoint between the pseudonasion and the rhinion.

nap. The greatest antero-posterior diameter of each anterior nasal aperture, i.e., the nostril length.

nb. The lateral diameter of each nasal aperture, i.e., the nostril breadth.

on. (*See* Wilder, p. 47.)

on^1. (*See* Wilder, p. 152.)

p. The point where the sagittal plane intersects a line joining the centres of the two parietal eminences.

pe. Parietal eminence.

po^1. The centre point of the external auditory meatus.

pr^1. The prosthion (*pr*^{1}.) in the living is 1 mm. below the prosthion (*pr.*) on the skull.

slm. The centre point in the sulcus mentolabialis.

sn^1. The centre point of the philtrum.

sor. The centre point of each superior orbital margin; an antero-posterior measurement of thickness.

sor^1. The centre point of the lower border of each eyebrow, immediately below *sor.*; an upward vertical measurement of thickness.

tl. Temporal point. The centre point of a line joining the parietal eminence to the external angular process of the frontal bone.

$\frac{tr.\text{–}g.}{2}$ The midpoint between the trichion and the glabella.

zy^1. The base of the zygomatic arch near the ear just above the tragion.

zy^2. The zygomatic tubercle.

zyg. Zygomagonion. The thickness of the cheek at a point midway between the lower edge of the zygoma and the gonion in a line joining the zygomatic angle and the gonion. (The zygomatic angle is the angle between the frontosphenoidal and temporal processes of the zygoma.)

zyo^1. } Points just behind (*zyo*^{1}.) and in front of (*zyo*^{2}.) the naso-labial fold, on a line joining the
zyo^2. } most projecting anterior inferior point of the zygoma with the angle of the mouth.

Anthropometric Measurements of two Australian Aboriginal Heads (known as H. B. 1 and D. B. 2).

			H. B. 1	D. B. 2
A.	General:			
	(1) Vertex–subnasale ...	*v.–sn.*	17·23 cm.	19·75 cm.
	(2) Trichion–pseudonasion ...	*tr.–n*^{1}.	Both somewhat bald	
B.	Cranium:			
	(1) Glabella–opisthocranion ...	*g.–op.*	19·8 cm.	21·3 cm.
	(2) Glabella–inion ...	*g.–i.*	19·65	20·2
	(3) Greatest breadth ...	*eu.–eu.*	14·3	14·35
	(4) Between the frontotemporalia	*ft.–ft.*	10·7	10·85
	(5) Bimastoid breadth ...	*ms*^{1}.–*ms*^{1}.	12·65	13·85
	(6) Tragion–tragion ...	*t.–t.*	14·5	14·95
	(7) Preaurale–preaurale ...	*pra.–pra.*	14·0	14·35
	(8) Trichion–pseudonasion ...	*tr.–n*^{1}.	—	—
	(9) Tragion–vertex ...	*t.–v.*	11·80	15·8
	(orthogonal projection)			
Auricular radiometer	(10) *po*^{1}.–vertex ...	*po*^{1}.–*v.*	11·8	13·75
	(11) *po*^{1}.–glabella ...	*po*^{1}.–*g.*	11·1	11·9
	(12) ...	*po*^{1}.–*on*^{1}.	11·15	12·1
	(13) Maximum frontal radius ...		11·25	11·98
	(14) ...	*po*^{1}.–*op.*	11·6	11·7
	(15) *po*^{1}.–inion ...	*po*^{1}.–*i.*	9·5	9·15

(The above measurements (auricular radiometer) were really taken from a dioptographic tracing, which gave an exact orthogonal projection of the head, and *po*[1]. was taken at the centre of the meatus. Hence they are projection measurements.)

			H. B. 1	D. B. 2
	(16) Maximum horizontal circumference		55·7 cm.	59·5 cm.
	(17) Longitudinal arc ...	*n*[1].–*i.*	33·8	38·0
	(18) Transverse arc, tragion–tragion	*t.*–*t.*	30·3	36·0
C.	THE FACE:			
	(1) Pseudonasion–stomion ...	*n*[1].–*sto.*	7·8	7·4
	(1 *a*) „ prosthion	*n*[1].–*pr*[1].	6·7	(no teeth)
	(2) „ gnathion ...	*n*[1].–*gn.*	12·6	11·5
	(3) Stomion–gnathion ...	*sto.*–*gn.*	5·0	4·6
	(4) Trichion–gnathion ...	*tr.*–*gn.*	—	—
	(5) Zygion–zygion ...	*zy.*–*zy.*	14·75	14·1
	(6) Intermalar breadth ...	*im.*–*im.*	12·9	12·7
	(7) Ectoconchion–ectoconchion	*ec.*–*ec.*	12·0	12·0
	(8) Ectocanthion–ectocanthion	*ex.*–*ex.*	10·2	9·2
	(9) Endocanthion–endocanthion	*en.*–*en.*	3·7	3·9
	(10) Gonion–gonion ...	*go.*–*go.*	13·35	11·0
	(11) Pseudonasion–glabella ...	*n*[1].–*g.*	1·9	1·75
	(12) Pseudonasion–commissural point	*n*[1].–*c.*	0·70	0·70
	(13) Ectocanthion–ectocanthion (tape)	2 (*n*[1].–*ec.*)	14·8	14·0
Auricular radiometer	(14) *po*[1].–prosthion ...	*po*[1].–*pr*[1].	11·3	—
Auricular radiometer	(15) *po*[1].–pogonion ...	*po*[1].–*pg.*	13·3	13·0
D.	THE NOSE:			
	(1) Pseudonasion–subnasale ...	*n*[1].–*sn.*	5·1	4·75
	(2) Alare–alare ...	*al.*–*al.*	5·0	5·7
	(3) Pronasale–subnasale ...	*prn.*–*sn.*	1·9	1·95
	(4) Pseudonasion–pronasale ...	*n*[1].–*prn.*	4·25	4·3
	(5) Pseudonasion–*la.* ...	*n*[1].–*la.*	5·61	5·13
	(6) Nostril length ...	*nap.*	R. 0·95	R. 1·0
			L. 0·95	L. 1·1
	(7) Nostril breadth ...	*nb.*	R. 1·3	R. 2·25
			L. 1·3	L. 1·85
Auricular radiometer	(8) *po*[1].–pseudonasion ...	*po*[1].–*n*[1].	10·3	10·65
Auricular radiometer	(9) *po*[1].–rhinion ...	*po*[1].–*rh.*	10·7	10·8
Auricular radiometer	(10) *po*[1].–pronasale ...	*po*[1].–*prn.*	10·9	12·4
E.	THE MOUTH:			
	(1) Cheilion–cheilion ...	*ch.*–*ch.*	6·75	6·00
	(2) Subnasale–stomion ...	*sn.*–*sto.*	3·25	2·95
	(3) Stomion–*slm.* ...	*sto.*–*slm.*	4·75	2·15
	(4) Subnasale–*slm.* ...	*sn.*–*slm.*	8·0	5·10
	(5) Labrale superius–labrale inferius	*ls.*–*li.*	2·65	1·80
Auricular radiometer	(6) *po*[1].–stomion ...	*po*[1].–*sto.*	12·4	12·7
F.	THE EAR:			
	(1) ...	*obs.*–*obi.*	R. 5·1	R. 5·45
			L. 5·1	L. 5·8
	(2) ...	*sba.*–*sa.*	R. 5·8	R. 7·45
			L. 6·0	L. 7·45
	(3) ...	*pa.*–*pra.*	R. 3·6	R. 3·9
			L. 3·6	L. 3·7
	(4) ...	*t.*–*tu.*	R. 3·3	R. 3·85
			L. 3·1	L. 2·75
	(5 ...	*sa.*–*ii.*	R. 4·8	R. 5·30
			L. 4·8	L. 5·30
	(6 ...	*ii.*–*sba.*	R. 1·95	R. 2·55
			L. 2·3	L. 2·55

Table of Thickness Measurements of Soft Parts.

			H. B. 1		D. B. 2
CRANIUM:	*op.*		0·40 cm.		0·80 cm.
	p.		0·60		0·90
	pe.	R.	0·45	R.	0·80
		L.	0·60	L.	0·80
	tr.		0·25?		0·40?
	$\frac{tr.-g.}{2}$		0·30		0·45
	g.		0·40		0·50
	g^1.	R.	0·35	R.	0·45
		L.	0·4	L.	0·5
FACE:	*sor.*	R.	0·50	R.	0·65
		L.	0·55	L.	0·80
	ior.	R.	0·45	R.	0·50
		L.	0·3	L.	0·60
	inf.	R.	1·5	R.	2·0
		L.	1·7	L.	2·2
	im.	R.	0·90	R.	0·7
		L.	0·90	L.	0·7
	zy.	R.	0·90	R.	0·8
		L.	0·70	L.	0·7
	zy^1.	R.	0·95	R.	1·2
		L.	0·95	L.	1·1
	zy^2.	R.	0·50	R.	0·5
		L.	0·6	L.	0·5
	tl.	R.	1·05	R.	1·0
		L.	1·05	L.	1·05
	zyg.	R.	1·8	R.	1·7
		L.	2·2	L.	1·7
	pg.		1·05		1·00
	gn.		1·10		0·60
	go^2.	R.	1·45	R.	1·10
		L.	1·30	L.	1·3
	go^1.	R.	1·60	R.	1·70
		L.	1·40	L.	1·5
	go.	R.	1·80	R.	1·20
		L.	1·50	L.	1·5
	zyo^1.	R.	2·15	R.	2·2
		L.	2·3	L.	2·0
	zyo^2.	R.	1·7	R.	—
		L.	1·5	L.	—
NOSE:	n^1.		0·4		0·75
	$\frac{n^1.-rh.}{2}$		0·3		0·55
	rh.		0·5		0·50
	lcl.	R.	0·8	R.	0·8
		L.	0·55	L.	1·0
MOUTH:	*sn.*		0·83		1·20
	sn.		0·80		1·20
	sto.		0·90		Edentulous
	slm.		1·10		1·20
	ms.		—	R.	1·50
			—	L.	1·20
	ms^1.		—	R.	0·55
			—	L.	0·60
	sor^1.		—	R.	1·0
			—	L.	1·0
	eap.		—	R.	0·2
			—	L.	0·3

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ON THE DEVELOPMENT OF THE CRANIAL MUSCLES OF TATUSIA AND MANIS

By F. H. EDGEWORTH, M.D.

(The figures referred to in text will be found as Plates at end of Article)

TATUSIA

Our knowledge of the adult anatomy of the cranial muscles in Xenarthra and Manidae is now fairly extensive, though the part played by the cervical nerves in the innervation of the hypobranchial spinal muscles, of the Subcutaneus colli and of the Cucullaris groups is in many cases still obscure.

Windle and Parsons, in 1899, gave a summary of what was then ascertained, and since that date many papers have been published dealing with individual muscles or groups of muscles. On the other hand, save for a few observations I published in 1914 and 1916, no account has been given of the development of these muscles, and the following paper is a contribution to the subject based on a study of *Tatusia novemcincta* and *Manis javanica*.

Knowledge of the adult anatomy of the cranial muscles of Tatusia has grown in the following way. Macalister (1872) described the facial and auricular muscles, the Sterno-mandibularis, Sterno-hyoideus, Sterno-thyroideus, Trapezius, Sterno- and Cleido-mastoideus, and a monogastric Digastric muscle "attached to beneath the jaw." Chaine (1900) described the Intermandibularis, Genio-hyoideus, and Genio-glossus; he did not mention the existence of any digastric muscle. Van Kampen (1905) mentioned the existence of a Stylomastoideus (here termed the "Interhyoideus dorsalis"). Lubosch (1908) described the Pterygo-tympanicus and the two Pterygoid muscles. Bijvoet (1908) identified the Digastric muscle of Macalister as a Mandibulo-auricularis, and stated that he could not find any Digastricus posterior or Stylo-hyoideus (his fig. No. 9, however, shows an unnamed muscle apparently identical with Toldt's Digastricus posterior). Toldt (1908) described a Digastricus posterior, taking origin from the temporal bone and passing down, band-like, to the lateral edge of the Sterno-mandibularis, where it was continued into an aponeurosis on the dorsal surface of that muscle, and was united to the posterior edge of the Intermandibularis. He also mentioned the existence of a Stylo-glossus. Fawcett (1921), in the course of his account of the development of the Chondrocranium, described the ocular muscles in the 12 mm. and the Stapedius in the 17 mm. embryo.

The embryological memoirs of Fernandez, Newman and Patterson, and Patterson, do not deal with the cranial muscles.

Masticatory muscles. In the 10 mm. embryo (figs. 1–4) the primordium of

the masticatory muscles is separated from the Intermandibularis and forms a mass above Meckel's cartilage. The muscles into which it develops are all formed and distinct but are not completely separated from one another. The upper end of the Temporalis is not attached to any skeletal structure; its inner surface is continuous with the Pterygoideus externus, and its lower end with the Masseter. The Pterygoideus externus passes backwards and outwards above Meckel's cartilage. The Pterygoideus internus passes backwards and downwards internal to Meckel's cartilage; its proximal end is continuous with the Pterygoideus externus and the Pterygo-tympanicus. The Pterygo-tympanicus passes backward for a short distance, but does not reach Meckel's cartilage. The Tensor tympani, the proximal end of which is continuous with that of the Pterygo-tympanicus, passes backwards and outwards towards the Malleus portion of Meckel's cartilage.

In the 12 mm. embryo (figs. 7–12) the muscles, with the exception of the Temporalis which is continuous with the Masseter, have become separated from one another. The Temporalis arises from the parietal plate, passes downwards and forks over the coronoid process of the primordium of the mandibula. The Masseter arises from the lower edge and inner surface of the primordium of the zygomatic arch, and passes down outside the primordium of the mandibula. The Pterygoideus externus is inserted into the condyloid process of the mandibula. The Pterygoideus internus is inserted into the inner surface of the mandibula below Meckel's cartilage.

Subsequent changes are as follows. In the 15, 17 and 20 mm. embryos (figs. 17–19) the proximal portion of the Tensor tympani has disappeared. The Pterygo-tympanicus takes origin just outside the primordium of the Pterygoid bone, below the Ala temporalis, and passes backwards towards the Malleus portion of Meckel's cartilage; it has no insertion into any skeletal element, the os tympanicus not being yet formed. From it arises the proximal end of the persisting distal portion of the Tensor tympani which passes backwards to the Malleus portion of Meckel's cartilage. In the 30 mm. embryo the Pterygoid bone had ossified, and the Pterygo-tympanicus takes origin from it; it passes backwards and forks, one limb is inserted into the tympanic bone, and the other is continuous by means of a fine tendon with the Tensor tympani, the origin of which, however, is mainly from the outer wall of the auditory capsule.

The Intermandibularis in the 10 mm. embryo (fig. 4) forms a transverse sheet between, but is not attached to, the two cartilages of Meckel. In the 12 mm. embryo (figs. 13 and 14) the posterior edge of the muscle diverges backward and is slightly concave, fitting up against the anterior surfaces of the salivary glands. In the 20 mm. embryo (fig. 28) the lateral edges of the muscle are attached to Meckel's cartilage.

There is no Digastricus anterior in the 10 mm. embryo. It is formed in the 12 mm. embryo (fig. 15)—apparently proliferated from the ventral surface of the Intermandibularis. It passes from the median raphé of the hinder part of

the Intermandibularis transversely outwards for a short distance, and has no lateral attachment. In the 20 mm. embryo (fig. 28) it has become oblique in position, passing forwards and outwards from the transverse aponeurosis of the Interhyoideus ventralis to the mandibula. In the 30 mm. embryo the attachments of the Digastricus anterior and Sterno-hyoideus superficialis to the transverse aponeurosis of the Interhyoideus ventralis are lost, and the two muscles form one continuous muscle-strip, the Sterno-mandibularis.

The hyoid muscle-plate in the 10 mm. embryo (figs. 1–4) is separated into the Stapedius and the Interhyoideus. The former lies in the fossa Stapedii and is inserted into the stapes. The Interhyoideus passes down close to the Hyale s. hyoid bar to a transverse aponeurosis just behind the posterior edge of the Intermandibularis. In the 12 mm. embryo (figs. 9–15) the Interhyoideus is partially separated into dorsal and ventral parts. The Interhyoideus has no upper attachment; it passes down postero-external to the Hyale and is partially inserted into it and is partially continuous with the Interhyoideus ventralis. The transverse aponeurosis of the latter is continuous anteriorly with a median raphé to which are attached the hinder fibres of the Intermandibularis and the inner ends of the Digastrici anteriores. In the embryo of 20 mm. the upper end of the Interhyoideus dorsalis has extended upwards to the outer surface of the auditory capsule.

Facial muscles and Subcutaneus colli. In the embryo of 10 mm. (fig. 4) the primordium of these muscles is visible as a collection of cells in front of and below the ear. It extends upwards a little in front of the ear. Behind the ear is the primordium of the Retrahens aurem. In the 12 mm. embryo (figs. 7, 8, 10, 12, 14,) the primordium has spread forwards to the angle of the mouth, and down the neck as the Platysma (using the nomenclature of Boas and Paulli). The Orbicularis oris is visible round the mouth (figs. 14, 15), and the primordium of the Mandibulo-auricularis just in front of the ear (figs. 7–8). The Retrahens aurem is partially separated into two muscles, and spreads outwards, fan-like, on the back of the Concha auris. In the embryo of 20 mm. (fig. 25) the Zygomaticus, Levator anguli oris, and the Orbicularis palpebrarum, have developed and the origin of the Mandibularis has extended downwards to the posterior edge of the primordium of the mandibula. The fibres of the Platysma can be traced from the surface of the Masseter to the shoulder girdle. In the adult (Macalister) they are attached to the lateral border of the dorsal shield.

The Branchio-hyoideus s. Subarcualis rectus i passes in the 10 and 12 mm. stages (figs. 3, 12) from the C. branchiale i forwards and inwards to the lower end of the C. hyale. In the 17 and 20 mm. stages—in which the C. hyale has begun to separate into parts—it is inserted into the Hypohyale. It is innervated by the IX.

The prehyoid hypobranchial spinal muscles, in the 12 mm. embryo (figs. 9–14) consist of Genio-hyoideus, Genio-glossus, Hyo-glossus, Stylo-glossus, Transversus linguae, Transversus hyoideus and Hyo-epiglotticus. The Genio-

hyoideus passes from the anterior end of Meckel's cartilage backwards to the basibranchiale and C. branchiale i. Its posterior part broadens, is concave dorsally in transverse section, and is ventral to the posterior part of the Hyo-glossus. In an embryo of 30 mm. the muscle forks posteriorly, into outer and inner fasciculi—the outer of which is attached to the C. branchiale i and the inner to the basibranchiale.

The Genio-glossus is not well defined in the 10 and 12 mm. embryos; in those of 15, 17 and 20 mm. (fig. 28) it forms a sharply-limited bundle which passes backwards ventral to the Transversus linguae. It does not reach the hyoid, nor spread upwards in the tongue.

The Hyo-glossus and Stylo-glossus are barely separable from each other in the 10 mm. embryo (figs. 2, 3), but are separate structures in the 12 mm. (figs. 9–12), and succeeding stages. The former arises from the basibranchiale and cornu branchiale i and passes forwards below the stylohyale into the tongue, just internal to the Stylo-glossus. The Stylo-glossus arises from the stylohyale and passes forwards and slightly inwards along the lateral border of the tongue; its anterior part separates into slender fasciculi.

The Transversus linguae forms a well-defined stratum of transverse fibres, with a median raphé (figs. 9–12). The fibres do not reach the lateral surface of the tongue. The muscle extends the whole length of the tongue, nearly as far as the hyoid bar. Just behind it, and probably developed by separation from it, are the Transversus hyoideus and Hyo-epiglotticus (figs. 10–12), which appear to be parts of one muscle. They lie dorsal to the basibranchiale. The fibres of the Transversus hyoideus pass across the middle line from the ventral end of one C. hyale to that of the other; those of the Hyo-epiglotticus pass from the C. hyale, on each side, backwards and inwards for a little distance. In the 20 mm. stage (figs. 24, 26) the lateral ends of the Transversus hyoideus are attached to the Hypohyalia, and the fibres of the Hyo-epiglotticus reach the primordium of the epiglottic cartilage.

The Transversus hyoideus and Hyo-epiglotticus are innervated by a recurrent branch of the lingual portion of the XIIth nerve.

In the 10 mm. embryo (fig. 5) the Rectus cervicis forms a flat antero-posterior strip in the neck. The inner edge joins that of its fellow. It has no posterior attachment. The Sterno-hyoideus superficialis separates from the ventral surface of the Rectus cervicis at the level of the thyroid cartilage and is inserted into the transverse aponeurosis of the Interhyoidei. The rest of the Rectus cervicis is inserted into the C. branchiale i. In the 12 mm. embryo (figs. 15, 16) the Sterno-hyoideus superficialis is separated from the Rectus cervicis throughout its whole length. The remaining part of the muscle is imperfectly separated into a median and a lateral part. The former is the Sterno-hyoideus, which is inserted into the basibranchiale and branchiale i. The lateral part forms the Sterno-thyroideus and Thyro-hyoideus, which are partially continuous. The Thyro-hyoideus is inserted anteriorly into C. branchiale i. In the 17 mm. embryo the posterior ends of the Sterno-hyoideus

superficialis, Sterno-hyoideus, and Sterno-thyroideus are attached to the dorsal surface of the Sternum at the level of the 2nd ribs, the first-named a little anterior to the other two.

In the 30 mm. embryo the posterior end of the Digastricus anterior and the anterior end of the Sterno-hyoideus superficialis have lost their attachments to the transverse aponeuroses of the Interhyoidei ventrales, and the muscles form a continuous structure—the Sterno-mandibularis.

The Trapezius in the 10 mm. (figs. 1–4) and 12 mm. (figs. 8–16) embryos is a continuous structure which arises from the dorsal fascia over the occipital region, and the neck, and anterior thoracic region. The anterior fibres pass backwards and downwards, the posterior fibres downwards. They are inserted into the acromial process of the scapula. A fasciculus—an incomplete Cleido-occipitalis—diverges from the ventral edge of the Trapezius and is inserted into the Clavicle external to the Cleido-mastoideus (figs. 9–15). In the 20 mm. embryo the Trapezius is separated into anterior and posterior portions; the former is inserted into the acromial process and the fascia over the Deltoid, whilst the latter, consisting of vertical fibres, is inserted into the outer surface of the acromial process.

The Sterno-mastoideus and Cleido-mastoideus in the 10 mm. embryo (figs. 2–4) are, with the exception of their anterior ends, separate structures. In the 12 mm. embryo (figs. 8–16) this anterior end is attached to the external surface of the auditory capsule. The Sterno-mastoideus passes backwards between the medial ends of the two clavicles—the sternum not yet being formed—whilst the Cleido-mastoideus is attached to the clavicle. In the 17 mm. embryo the former is attached to the anterior surface of the sternum at the level of the 1st rib.

Pharyngeal muscles. In the 10 mm. embryo (figs. 1–4) the Stylo-pharyngeus and Constrictor pharyngis form a continuous sheet on the dorsi-lateral surface of the pharynx. It is continuous posteriorly with the Constrictor oesophagi, and is not yet attached to skeletal structures. There is a slight palato-pharyngeal fold of the pharyngeal wall in the hyoid segment. In the 12 mm. embryo (figs. 9–16) the Stylo-pharyngeus and Constrictor pharyngis are attached laterally to the C. hyale, C. branchiale i, thyroid and cricoid cartilages. The Palato-pharyngeus has developed on the inner side of the fore part of the muscle sheet. In the 20 mm. embryo (fig. 20) the palatal folds meet in the middle line and are continuous posteriorly with the palato-pharyngeal folds. The Palato-pharyngeus has extended forwards ventro-external to the pharyngeal end of the Eustachian tube. In the 30 mm. embryo (figs. 29–31) the Constrictor pharyngis and Stylo-pharyngeus sheet forms, posteriorly, a Constrictor muscle, the dorsal edge of which meets that of its fellow. Further forwards it forms a longitudinal muscle which, anteriorly, turns inwards in the soft palate. In the anterior part of the pharynx is a thin transverse muscle; its outer part is ventro-external to the pharyngeal end of the Eustachian tube, whilst its inner part curves forwards into the soft palate dorsal to the muscle-

sheet formed by the Stylo-pharyngeus and Constrictor pharyngis. It is probable that this is formed by a transformation of the anterior part of the Palato-pharyngeus, whilst the posterior part of the muscle disappears. Stages between the 20 and the 30 mm. embryos were not available for affording evidence of these changes.

The Crico-thyroideus, passing from the cricoid to the thyroid cartilage, is already developed in the 10 mm. embryo (fig. 16, from the 12 mm. embryo).

Laryngeal muscles. In the embryo of 10 mm. (fig. 4) the primordium of the laryngeal muscles is situated in the larynx, and is not as yet differentiated into the muscles eventually derived from it. In the embryo of 12 mm. (figs. 13–16) these consist of the following: (*a*) Dilatator laryngis s. Crico-arytenoideus posticus, which takes origin from the dorsal surface of the cricoid cartilage and lateral side of its median crista and passes forwards and outwards to the processus muscularis of the arytenoid cartilage; (*b*) Laryngeus dorsalis s. Interarytenoideus, which is very minute and lies on the dorsal side of the arytenoid cartilages; (*c*) Laryngeus ventralis, which has as yet no origin, its fibres passing upwards to the arytenoid cartilage. In the embryo of 20 mm. (figs. 21–27), the Interarytenoideus takes origin from the dorsi-lateral surface of the arytenoid cartilage and passes upwards and forwards to a median raphé which is continued forward from the interarytenoid bridge. The Laryngeus ventralis is separated into the Crico-arytenoideus lateralis and Thyro-arytenoideus. The former arises from the anterior edge of the lateral part of the cricoid cartilage and is inserted into the processus muscularis of the arytenoid cartilage. The Thyro-arytenoideus takes origin from the thyroid cartilage, and is partially separated into Thyro-arytenoideus superior and inferior.

MANIS

The cranial muscles of Manis have been described by a number of investigators. Macalister (1872) described the Platysma, Trapezius, Sterno-mastoideus, Sterno-glossus, the two orbicular muscles, and the Levator labii superioris; and mentioned a Cleido-mastoideus. Ehlers (1894) described the lingual musculature in *Manis macrura* and *M. tricuspis*. Kohlbrugge (1898) stated that there is no Sterno-hyoideus, Genio-hyoideus, Omo-hyoideus, Stylo-pharyngeus, Stylo-hyoideus, nor any muscle associated with the aural concha ("Ohrmuschel"). He described the Buccinator, Digastricus, Subcutaneus colli (with an innervation from cervical nerves, the VIIth being distributed to the face only, the Sterno-thyroideus (innervation from Ni. Cervs. ii and iii), Thyro-hyoideus (innervation from XII), and muscles of the tongue. These he said, lie in a sheath in front of the trachea and extend to the xiphoid. The sheath consists of an outer mantle formed by the Intermandibularis (innervation by V) which is attached to the jaw and base of the skull; to it pass fasciculi attached to the hyoid; and an inner mantle extending into the thorax and probably derived from the Genio-glossus, as it is innervated by the XII. There is a special muscle (innervation not determined) for the salivary gland, which

springs from the angle of the jaw close to the insertion of the Digastricus. Eschweiler (1898–99) described the Stapedius, and a strong unnamed muscle passing to the pharynx and attached to the cartilage of the Eustachian tube, and stated that there is no Tensor tympani. Windle and Parsons (1899) described the Masseter and a Digastric muscle inserted to an area on the jaw midway between the angle and the symphysis. Toldt (1906) stated that there is an equivalent of a Digastricus anterior in the form of a "Hyo-mandibularis," but gave no description. Schulman (1906) described the Masseter, the Pterygo-tympanicus (under the name Pterygo-spinosus) and Tensor veli palatini. Lubosch (1908) described the Temporalis, and a Pterygoideus internus, and stated that there is no Pterygoideus externus. I have stated previously (1914) that there is no Digastricus anterior (this, however, is an error, *vide infra*), described the Interhyoideus, and identified the Digastricus of Kohlbrugge, and of Windle and Parsons, as a Mandibulo-auricularis. The memoirs on the development of Manis by Weber, and by van Oordt, do not deal with the cranial muscles.

Eye muscles. The primordia of the eye muscles in an embryo of 10 mm. (figs. 40–42) consist of three cell masses representing the premandibular somite, the Obliquus superior, and the Rectus externus. Each one consists of an aggregate of cells, with no trace of any epithelium. The premandibular somite is triangular in shape, with its base towards the eyeball, and its apex directed towards the hypophysis. In an embryo of 14 mm. the premandibular somite has separated into the Rectus superior, internus, and inferior, and the Obliquus inferior. The Obliquus superior gains an origin from the Ala orbitalis, and the Obliquus inferior one from the nasal capsule (fig. 59). The other muscles gain an attachment to a slight lateral process at the base of the Ala orbitalis.

Masticatory muscles. In the 10 mm. embryo (figs. 41–43) the primordium of the masticatory muscles is a continuous ∩-shaped structure, open posteriorly, and embracing the R. mandibularis v. It is partially separated into a lateral portion, into which passes the R. lateralis, and a medial portion. The lateral portion has a slight upward projection lateral to the R. mandibularis v, and a downward projection lateral to the faintly-marked-out primordium of Meckel's cartilage. In the 13 mm. embryo (fig. 45) the primordia of the Pterygoideus externus and Temporalis are distinguishable in the lateral portion of the mass. In the 14 mm. embryo (figs. 48, 50) separation into muscles has taken place. The lateral portion is separated into Temporalis, Pterygoideus externus, and Masseter. The two former have as yet no origins, the Masseter arises from the inner surface and lower margin of the zygomatic portion of the superior maxilla. The medial portion has separated into Pterygoideus internus, Pterygo-tympanicus, and Pterygo-hyoideus. Neither has attained an attachment of origin. The Pterygoideus internus passes internal to Meckel's cartilage towards the primordium of the mandibula. The Pterygo-hyoideus passes backwards, internal to the upper edge of the Intermandibularis posterior, towards, but

not yet reaching, the C. hyale. In the 18½ mm. embryo the Pterygoideus internus has disappeared, and the posterior end of the Pterygo-hyoideus reaches the C. hyale. In the 21 mm. embryo (figs. 59, 60) the inner portion of the Masseter has separated from the outer portion, and forms the Zygomatico-mandibularis, which arises from the inner surface of the zygomatic portion of the superior maxilla. It is still more oblique in position than the Masseter, which arises from the lower edge of the superior maxilla. The Pterygoideus externus arises from the Palate bone and is inserted into the condyloid process of the jaw. The Pterygo-tympanicus lies lateral to the ventral process of the base of the Ala temporalis; a process projects from its upper part towards the os tympanicum (the Pterygo-tympanicus proper) whilst its ventral end extends downwards, forwards and inwards, in front of the Pterygoid bone, into the soft palate (Tensor veli palatini).

Intermandibularis. In an embryo of 10 mm. (fig. 43) the Intermandibularis is not continuous with the primordium of the masticatory muscles, nor has it any attachment to Meckel's cartilage. It has spread backwards a little. In an embryo of 14 mm. (fig. 52, 53), it has spread still further back and has separated into anterior and posterior parts. The Intermandibularis anterior is attached to the primordium of the mandibula, but the Intermandibularis posterior has no dorsal attachment. Each meets its fellow in a ventral median raphé, ventral to the Sterno-glossi. The dorsal edge of the Intermandibularis posterior extends upwards, and in an embryo of 21½ mm. is attached to the Pterygoid bone.

The Digastricus anterior is not yet developed in an embryo of 10 mm. In one of 14 mm. (figs. 52, 53) it is formed, and is a longitudinal muscle on the outer side of the Intermandibularis anterior and posterior, and like them is innervated by the N. mandibularis v. It is attached anteriorly to the primordium of the mandibula, just in front of the anterior edge of the Intermandibularis anterior. Traced backwards, it is found partially to separate into two fasciculi, one of which is attached to the C. hyale and the other to the inner surface of the salivary gland.

Hyoid muscles. In an embryo of 10 mm. (figs. 40, 41, 43) the hyoid bar consists of a continuous precartilaginous Stapes, Interhyale, and C. hyale. There is no artery perforating the Stapes at this or any subsequent stage. There is no crista parotica, or laterohyale, or fossa stapedii. The hyoid muscle-plate has separated into a Stapedius and Interhyoideus. The former (fig. 41) has not yet attained an attachment of origin and lies on the outer side of the auditory capsule, internal to the VIIth nerve; it is inserted into the Interhyale. In a 14 mm. embryo (figs. 46–52) the Interhyale has disappeared, and the Stapes is in contact with the Incus. The crista parotica and laterohyale have developed; the latter has no connection with the C. hyale. The Stapedius lies in the fossa stapedii, and is inserted into the Stapes. The Interhyoideus takes origin from the C. hyale, passes downwards and inwards and meets its fellow in a ventral raphé ventral to the Sternoglossi and posterior to the Intermandibularis posterior. In an embryo of 18½ mm. (figs. 55–58) the Interhyoideus

has spread backwards—as far as the anterior end of the sternum, and forms an outer ventro-lateral sheath for the Sterno-glossi. It maintains its origin from the C. hyale, and is innervated by the R. hyoideus VII.

Facial muscles and Subcutaneus colli. The primordium of these muscles is first visible in the 10 mm. embryo (fig. 43) as an aggregate of cells in the hyoid segment, just beneath the ectoderm, and with no relations to the Interhyoideus. In the 14 mm. embryo it has spread extensively on to the face, extending forwards over the Masseter, upwards in front of the ear and upwards behind the ear. In the neck the back-growth forms the Sphincter externus and the Platysma (fig. 50). The former is a thin sheath of transverse fibres in the lateral and ventral parts of the neck. The Platysma is a thin narrow band, which is continuous anteriorly with the Sphincter externus; it extends backwards and slightly inwards towards the manubrium sterni. There is no Sphincter internus. In the 18½ mm. embryo (figs. 55–59) the Orbicularis palpebrarum, Orbicularis oris, and Levator labii superioris, are formed from a still further forward growth of this muscle-sheet on to the face, the Mandibulo-auricularis arises from the upgrowth in front of the ear, and a small Retrahens aurem from that behind the ear.

Hypobranchial spinal muscles. In an 8·5 (A) mm. (figs. 33–36) embryo the primordium of the hypobranchial spinal muscles is a continuous cell-column extending from the mandibular segment backward in the neck to an antero-posterior level a little posterior to the 6th aortic arch. Its posterior part lies dorsi-lateral to the coelom, which at this stage extends as far forwards as the 3rd branchial segment. In a second 8·5 mm. embryo (B)—of the same size but more advanced in development—the coelom has retreated in the neck and its anterior limit is at the level of the limb-bud. The muscle-primordium has extended backward laterally to the coelom. In a 10 mm. embryo (figs. 43–44) the primordium has separated, at the level of the 1st branchial bar, into anterior and posterior portions.

In a 14 mm. embryo (figs. 52, 53) the posterior part or Rectus cervicis is separated into a lateral and a median portion. The lateral portion forms anteriorly the Thyro-hyoideus and posteriorly the Sterno-thyroideus. The Thyro-hyoideus extends from the thyroid cartilage to the C. branchiale i. The posterior end of the Sterno-thyroideus extends backward in the thorax. The median portion of the Rectus cervicis forms the Sterno-hyoideus; its anterior end is fused with the posterior end of the Hyo-glossus to form a Sterno-glossus, which extends from the anterior end of the tongue into the thorax. The prebranchial portion of the hypobranchial spinal muscles forms the Genio-hyoideus, Genio-glossus, and the Transversus linguae, in addition to the Hyo-glossus. The Genio-hyoideus is attached anteriorly to the primordium of the mandibula; it extends backward, joining its fellow, below the Sterno-glossi to a point a little posterior to the level of the Interhyoidei, but at this stage no further. The Genio-glossus is attached anteriorly to the primordium of the mandibula, and extends backwards, close to the middle line, as far as the level

of the hyoid bar. The Transversus linguae forms a transverse band of fibres, the median edge of which is inserted into the lingual raphé.

In an 18·5 mm. embryo (figs. 55–58) the Genio-hyoidei have extended back to the level of the anterior end of the sternum, and are partially separated into median and ventro-lateral portions, which form an inner ventral sheath of the Sterno-glossi. The Transversus linguae has extended back to the level of the cricoid cartilage forming a dorsal inner sheath for the Sterno-glossi. The posterior ends of the Sterno-glossi are attached to the bifid posterior end of the sternum, those of the Sterno-thyroidei to the dorsal surface of the sternum at the level of the attachment of the 7th ribs.

Cucullaris. (By this term I denote the common primordium of the Trapezius, Cephalo-humeralis, and Sterno-mastoideus). It is first visible in a 8·5 (A) mm. embryo (fig. 32). At this stage the 3rd and 4th gill-clefts are separated from the endoderm, but their outer ends are continuous with the ectoderm. The median end of the 4th cleft extends a little further forwards than that of the 3rd, and the posterior end of the 3rd extends further back than does that of the 4th. The 4th aortic arch, i.e. that of the 2nd branchial segment, which is well developed in a 6 mm. embryo, is now, for the most part, atrophied and its remains are visible between the 3rd and 4th gill-clefts. The Cucullaris, to which the XIth nerve passes, is visible as an aggregate of cells, the ventral end of which is lateral to the small gap between the 3rd and 4th clefts, i.e. in the 2nd branchial segment. It extends forwards for the length of 230 μ, but does not extend backwards into the 3rd branchial segment.

In the 10 mm. embryo (figs. 43, 44) the Cucullaris extends backwards in the neck, but does not reach the region of the fore-limb. The Sterno-mastoideus has separated off from its posterior part.

In the 14 mm. embryo the Sterno-mastoideus, which has no attachments, is a separate structure. The Occipito-humeralis diverges from the ventral edge of the Trapezius, and is inserted into the humerus by two fasciculi, the dorsal of which has an insertion in common with the Deltoid, and the lower is inserted just below the Pectoralis. The Trapezius has spread backwards, a little beyond the scapula.

In the 18 mm. embryo the anterior end of the Sterno-mastoideus is attached to the auditory capsule, and its posterior end to the side of the manubrium steni. The Trapezius is attached to the spine of the scapula.

The Pharyngeal muscles are not yet formed in a 8·5 mm. embryo. In one of 10 mm. (figs. 43, 44) they consist of a Stylo-pharyngeus in the region of the hyoid and 1st branchial bars, and of a Constrictor pharyngis in that of the thyroid cartilage. In an embryo of 14 mm. (figs. 47–49) the Constrictor pharyngis, which is continuous posteriorly with the Constrictor oesophagi, extends forwards to the naso-pharynx, overlapping the Stylo-pharyngeus. The Stylo-pharyngeus (fig. 49) is attached to the C. hyale, it passes inwards and then upwards, hooking round the ventral edge of the Constrictor pharyngis. The palato-pharyngeal fold is slightly developed. Dorsal to it, and internal to

the Constrictor pharyngis is the Palato-pharyngeus muscle (figs. 47, 48). In an embryo of 21·5 mm. the ventral edge of the Constrictor pharyngis is attached to the C. branchiale i, the thyroid ala, and the cricoid cartilage (figs. 61–63). The palato-pharyngeal fold is continuous anteriorly with the soft palate. The Palato-pharyngeus extends forward in the soft palate, and its anterior edge is attached to the Pterygoid bone (fig. 60).

Laryngeal muscles. In the 8·5 mm. (A) embryo (figs. 32–36) the 3rd and 4th gill-clefts are continuous with the ectoderm, but not with the endoderm. The postbranchial body is a thickening of the lateral margin of the pharyngeal epithelium. There is no 2nd branchial nerve between the 3rd and 4th gill-clefts, the 4th aortic arch is represented by remnants only. The superior laryngeal nerve is the 3rd branchial nerve, entering the laryngeal region between the level of the 4th gill-cleft and the post-branchial body. The Aditus laryngis is bounded by the Plicae laterales. The primordium of the laryngeal muscles is postbranchial in position, extending from 90 μ behind to the level of the hinder margin of the postbranchial body; its hinder end is continuous with the primordium of the Constrictor oesophagi. The recurrent laryngeal nerve passes transversely inwards from the vagus, behind the 6th aortic arch, to the hind end of the primordium of the laryngeal muscles.

In the 8·5 mm. (B) embryo (figs. 37–39) the Plicae inferiores have developed and bound the Aditus laryngis, their anterior ends abut against but do not join the back of the epiglottis (fig. 47). The front end of the laryngeal muscle primordium is 70 μ in front of the postbranchial body, i.e. in the 3rd branchial segment. The hind end of the primordium is separated from the Constrictor oesophagi.

In the 8·5 mm. (B) embryo (fig. 38) the primordium of the thyroid cartilage has appeared at the level of the superior laryngeal nerve, i.e. in the 3rd branchial segment. In the 10 mm. embryo (fig. 44) there is a continuous primordium of the arytenoid and cricoid cartilages. The primordium of the laryngeal muscles is wholly in front of the postbranchial body (which is still continuous with the pharyngeal endoderm) and so branchial in position. It is not separated into portions.

In the 14 mm. embryo (figs. 48, 49, 51) the primordia of the arytenoid cartilages have partially separated from that of the cricoid cartilage; they are connected by a transverse dorsal bridge. The primordium of the laryngeal muscles has separated into a Dilatator laryngis (Crico-arytenoideus posticus), Laryngeus dorsalis (lateral half of the Interarytenoideus) and Laryngeus ventralis (Thyro-arytenoideus).

In the 18·5 mm. embryo (figs. 55–58) the Thyro-arytenoideus arises from the basithyroid and from its posterior projection, which is tied to the Cricoid of a ligament.

In the 21·5 mm. embryo (cp. figs. 56 and 61) the dorsal bridge connecting the arytenoid cartilages has disappeared. The Thyro-arytenoideus has partially separated into the Thyro-arytenoideus superior arising from the Basithyroid and the Thyro-arytenoideus inferior arising from its posterior median process.

Comments.

The above recorded investigations afford an explanation of some of the many problems presented by the adult anatomy of the cranial muscles of Xenarthra and Manidae.

The primordium of the masticatory muscles in Tatusia separates into Temporalis, Masseter, Pterygoideus externus, Pterygoideus internus, Pterygo-tympanicus, and Tensor tympani. In Manis it separates into Temporalis, embryonic Masseter, Pterygoideus externus, Pterygoideus internus, the primordium of the Pterygo-tympanicus and Tensor veli palatini, and the Pterygo-hyoideus.

In Tatusia no Zygomatico-mandibularis is separated from the Masseter, which arises from the lower edge and ventro-medial surface of the zygomatic arch. A Zygomatico-mandibularis is not invariably present in Xenarthra. It is absent in Tamandua and Myrmecophaga, whilst it is formed in Bradypus, Choloepus, Dasypus, and Tolypeutes. In Manis the Masseter of earlier stages separates into the Zygomatico-mandibularis arising from the inner surface, and the Masseter arising from the lower edge of the superior maxilla.

The appearances in the 10 mm. stage of Tatusia, and the 13 mm. stage of Manis, show that Pterygoideus externus in its earliest stage is as closely associated with the Pterygoideus internus as with the Temporalis, but this is probably a secondary phenomenon related to its development during intra-uterine life, for in Dasyurus, where the Pterygoideus externus is formed after birth, it is developed from the primordium of the Temporalis and Masseter and has no relations with the Pterygoideus internus. This agrees with the innervation—for the Temporalis, Masseter, Zygomatico-mandibularis, and the Pterygoideus externus are innervated from the R. lateralis of the R. mandibularis v.

The Pterygoideus externus is present in all Xenarthra, arising by a single head in Bradypus and Chlamydophorus, by two heads in Tatusia, Tamandua, and Dasypus.

The Pterygoideus externus of Manis was considered by Lubosch to be a Pterygoideus internus—but in the embryo it arises from the palate bone (as in the adult) and passes backwards and outwards to the jaw dorsal to Meckel's cartilage—a course which shows that the muscle is a Pterygoideus externus. Further, it is innervated from the R. lateralis of the R. mandibularis v. The Pterygoideus internus of Manis atrophies—during its existence it passes characteristically downwards towards the primordium of the jaw internal to Meckel's cartilage. The muscle next behind the Pterygoideus internus forms in Tatusia the Pterygo-tympanicus, in Manis it forms both a Pterygo-tympanicus and a Tensor veli palatini, which remain in continuity even in the adult (Schulman). This formation of both muscles from the same primordium is not peculiar to Manis, for it also occurs in Dasypus sexcinctus (Kostanecki) and in Bradypus marmoratus.

The existence of the Pterygo-tympanicus in Xenarthra and Manidae is probably a primitive Mammalian feature, for the muscle is present in Ornithorhynchus. It does not occur in Marsupials, where the homologous primordium forms the Tensor veli palatini only, nor in any other Mammalian group —as far as is known.

In Tatusia there is a normal Tensor tympani. In later developmental stages the proximal portion disappears, and the proximal end of the persisting distal portion becomes attached to the Pterygo-tympanicus and the wall of the auditory capsule. This is similar to the occurrences in Dasyurus and the rabbit.

Eschweiler stated that there is no Tensor tympani in Manis, and study of these embryos confirms the statement. There is, however, a Pterygo-hyoideus muscle, which is innervated by the R. medialis of the R. mandibularis v. In the 14 mm. stage its primordium lies immediately behind that of the Pterygo-tympanicus and Tensor veli palati, in a position which agrees with that of the Tensor tympani of Tatusia. This, and the innervation, show that it is the homologue of the Tensor tympani of other Mammals.

Lubosch, from a study of the adult condition of the Pterygoid bone in Xenarthra and Manidae, was led to the opinion that in Bradypus, Choloepus, Myrmecophaga, Tatusia, Priodontes, Xenurus, and Manis, it is formed by a fusion of a Parasphenoid and a Parabasale. The theory, however, can be rejected for Tatusia and Manis, as in these animals the bone is formed from one centre only, behind that of the Palate bone.

Schulman and Toldt were of opinion that the Detrahens mandibulae of Monotremes is a muscle which is not present in any other Mammalian order.

It has not been found in Marsupials, nor is it developed in Tatusia or Manis. It is possible, however, that it exists in some Xenarthra, for Lubosch described a muscle in Tamandua, Dasypus, and Tolypeutes, under the title "Accessory head of the Masseter," which arises from the Tympanicum and passes downwards behind the Masseter to the angle of the jaw. It is innervated in Tamandua and Dasypus by a branch of the N. auriculo-temporalis v.

The innervation—determined by Lubosch—excludes the possibility that the muscle is a Mandibulo-auricularis, whereas this and the situation of the muscle suggest that it is homologous with the Detrahens mandibulae of Monotremes.

There is no record of any similar muscle in Choloepus by Mackintosh, nor in Myrmecophaga by Owen or Pouchet. The muscle in Bradypus called "Digastric" by Windle and Parsons, and the (variable) muscle in Chlamydophorus called "Digastric" by Macalister may be either homologous structures or instances of a Mandibulo-auricularis, for the innervation is not yet known.

Stapedius. In the 10 mm. stage of Manis the Stapedius is situated external to the auditory capsule, and is inserted into the Interhyale. Subsequently, on development of the crista parotica and fossa stapedii and disappearance of the Interhyale, the origin of the muscle shifts to the floor of the fossa stapedii and the insertion to the stapes. The corresponding early stages of Tatusia were not available.

These phenomena are in harmony with those previously published which show that the Stapedius was originally a Levator hyoidei—a condition which is the permanent one in Monotremes.

The upper end of the Interhyoideus in the embryos of *Tatusia novemcincta* I examined extended upwards to the mastoid process and the muscle became divided into dorsal and ventral portions, the former inserted into and the latter arising from, the C. hyale. The same arrangement must have occurred in the adult specimen examined by van Kampen (who, however, described only the upper part—under the name Stylo-mastoideus). On the other hand, the Interhyoideus was described by Chaine and by Toldt as a single muscle arising from the mastoid process. This variation is not surprising, seeing how close the muscle is to the C. hyale. A similar variation occurs in Choloepus.

The varieties in the form of the Interhyoideus among Xenarthra are as follows. It is single and arises from the C. hyale in Chlamydophorus and Tolypeutes; single and arises from the C. hyale and Mastoid in *Dasypus villosus*; single and arises from the Mastoid in *Bradypus tridactylus*. It is separated into upper and lower portions in *Bradypus marmoratus*, Myrmecophaga, and Tamandua. It arises from the Mastoid and is either single or separated into upper and lower portions in Choloepus and Tatusia.

These variations suggest that Xenarthra are descended from forms possessing a digastric muscle, the posterior belly of which, i.e. the Interhyoideus, arose from the C. hyale. The other conditions present result from upgrowth of the dorsal end of the muscle and, in some species, its division into dorsal and ventral portions—the Interhyoideus dorsalis and ventralis.

The anterior element of the Sterno-mandibularis is—as was pointed out by Toldt—the representative of the Digastricus anterior. Its development in Tatusia shows that it is at first a transverse muscle which subsequently rotates into a longitudinal position with its original inner end posterior. This negatives Toldt's theory that the muscle is primarily longitudinal, a theory which fails to account for the transverse position of the muscle in Monotremes—a position it has from the first stage of its development—and also fails to account for the rotation of the muscle from a transverse to a longitudinal position in successive stages of development in Dasyurus. In fact all the known developmental phenomena go to show the truth of Schulman's theory that the muscle when first developed consisted, like its "Muttermuskel," the Intermandibularis, of transverse fibres.

The transverse aponeurosis of the Interhyoideus, or Interhyoideus ventralis, is identical with, or forms a part of, the tendinous intersection in the Sterno-mandibularis in Bradypus, Choloepus, and Tolypeutes; whilst it passes dorsally to the Sterno-mandibularis in Myrmecophaga, Tamandua, Dasypus, and Tatusia. The above described developmental changes in Tatusia show that the condition of a continuous Sterno-mandibularis is secondary to one with an intersection. The non-attachment of the Interhyoideus or Interhyoideus ventralis to the Digastricus anterior in Myrmecophaga, Tamandua, Dasypus,

and Tatusia, is thus secondary only—it is not a primitive feature as is the case in Monotremes.

The posterior part of the Sterno-mandibularis s. Sterno-hyoideus superficialis is either a medial strip of the Sterno-hyoideus (Bradypus), or a superficial strip of either this muscle (Dasypus, Tatusia, Tolypeutes, Chlamydophorus), or of the Sterno-glossus (Myrmecophaga), or of the Sterno-genioideus (Tamandua). In the two last named animals there is no Sterno-hyoideus, so it is probable that this is represented by the posterior constituent of these muscles. The posterior part of the Sterno-mandibularis is thus not homologous with the whole of a Sterno-hyoideus in any instance.

The first steps in the formation of a Sterno-mandibularis in Xenarthra would thus appear to have been the separation of a Sterno-hyoideus superficialis from the Sterno-hyoideus, and the fixation of its anterior end to the transverse aponeurosis of an Interhyoideus.

In Dasypus, according to Toldt, the anterior portion of the Sterno-mandibularis is innervated by the vth, and the posterior portion by the xiith and N. Cerv. ii. In a 20 mm. embryo of Tatusia the anterior portion is innervated by the vth, and the posterior by the R. descendens xii. The xii before giving off this R. descendens is joined by a branch from N. Cerv. i. In Tamandua, according to Toldt, the whole of the Sterno-mandibularis is innervated by the vth. This seems a remarkable statement and needs verification. The innervation of the muscle is not known in other Xenarthra.

A Digastricus anterior is present in Manis. It is not yet developed in the 10 mm. embryo, and in the 13 and 14 mm. embryos forms a longitudinal muscle just external to the Intermandibularis. It arises from the primordium of the mandibula in front of the anterior edge of the Intermandibularis anterior, at about the junction of the anterior and middle thirds of Meckel's cartilage. It passes backwards and is partially separated into two fasciculi, one of which is attached to the C. hyale and the other to the inner surface of the salivary gland. It is innervated by the N. mandibularis v. Embryos of intermediate sizes were not available, so that the early stages in the development of the muscle could not be determined, but its relations to the Intermandibularis and its innervation show that the muscle is a Digastricus anterior.

The transformation of the Tensor tympani and Digastricus anterior into protractors of the hyoid bar is perhaps related to the non-development of any attachment of the Genio-hyoideus to it.

In *Manis javanica* the Interhyoideus arises from the C. hyale. In the 14 mm. embryo the muscle forms a vertical band, with a ventral median raphé, just behind the Intermandibularis. In later stages the ventral part of the muscle spreads backwards—in a 21 mm. embryo as far as the anterior end of the sternum—forming the posterior part of the outer sheath of the Sterno-glossi, the anterior part being formed by the Intermandibularis.

The Interhyoideus of Tatusia and *Manis javanica* is innervated by the R. hyoideus vii.

Ehlers described, in *Manis tricuspis* and *macrura*, a Glosso-vaginalis superficialis, spreading from the jaws down the whole length of the Sterno-glossi. There was also a portion of this Glosso-vaginalis superficialis which arose from the bulla tympanica and passed ventrally, superficial to the main sheet. The condition of the specimens did not allow of dissection of the nerves. Ehlers identified the main sheet with a Mylohyoid, i.e. an Intermandibularis and the superficial vertical strip with a Stylo-hyoideus.

Investigation of the nerve supply in better specimens would show whether the condition is as he stated, or whether—as is more probable—it is similar to that of an adult *Manis javanica*. The figure given by Ehlers admits of either interpretation. In either case the condition shows that the origin of the Interhyoideus may in Manidae spread up to the skull, just as in Xenarthra.

The lingual musculature in *Manis javanica* is formed by the Hyo-glossus, Sterno-hyoideus, Genio-glossus, Transversus linguae. A Stylo-glossus is not developed—an occurrence which suggests that the muscle here called Hyo-glossus is homologous with the primordium of the Hyo-glossus and Stylo-glossus of Tatusia, and not merely with the former muscle. The Genio-glossus[1] is similar to that of Tatusia. The Hyo-glossus and Sterno-hyoideus fuse and form a continuous Sterno-glossus, the hind end of which is attached to the bifid end of the sternum. The tongue has an outer and an inner sheath. The former is formed by the Intermandibularis and Interhyoideus. The Genio-hyoideus joins its fellow and grows backwards, as a ventral median and two ventro-lateral bands[2], forming a ventro-lateral inner sheath to the Sterno-glossi. The Transversus linguae extends backwards as far as the cricoid and forms, in part, an inner dorsal sheath of the Sterno-glossi. The Hyo-glossus, Genio-hyoideus, and Sterno-hyoideus, do not gain any temporary attachment to the Hyo-branchial skeleton. In both Tatusia and Manis there are Thyro-hyoideus and Sterno-thyroideus, muscles. Their adjacent ends, which are partially continuous, are attached to the thyroid cartilage. In Manis the hind end of the Sterno-thyroideus, like that of the Sterno-glossus, grows backwards in the thorax.

In the 20 mm. stage of Tatusia the Thyro-hyoideus, Sterno-thyroideus, and Sterno-hyoideus, are innervated by the R. descendens XII, and the pre-hyoid hypobranchial spinal muscles by the lingual division of the nerve. In Manis, according to Kohlbrugge, the lingual musculature is innervated by two branches of the XII. The Genio-glossus, Transversus linguae, Genio-hyoideus are innervated by the anterior branch, and the Sterno-hyoideus constituent of the Sterno-glossus by the posterior branch (which might be called the R. descendens XII). The Thyro-hyoideus is innervated by a branch of the anterior division. The Sterno-thyroideus is innervated by the Ni. Cervs. ii and iii and not by the XII.

Facial muscles and Subcutaneus colli. In Manis the primordium of the

[1] Glossovaginalis profundis, stratum internum, of Ehlers.

[2] Glossovaginalis profundus, stratum medium and stratum externum, of Ehlers.

facial muscles and Subcutaneus colli develops in the hyoid segment and spreads forwards and upwards in front of the ear and backwards in the neck. In Tatusia the earliest stage was not available—in the 10 mm. stage the primordium had spread back into the 1st branchial segment. These phenomena are similar to those already described in Dasyurus and the pig. The upward growth in front of the ear forms the Mandibulo-auricularis in both animals.

Bijvoet found that in Tatusia the branch of the VIIth to the Mandibulo-auricularis passes upwards in front of the ear. The same course was followed in the embryos of Manis examined as well as in Tatusia. This is what might be expected from the developmental phenomena. On the other hand Schulman found in many Mammals, including Myrmecophaga, that the branch of the VIIth to the muscle passes round the back of the ear and forwards above it. He concluded that the "Mandibulo-auricularis trotz seiner vorgeschobenen Lage morphologisch mit den postauricularen Facialisgebiet zusammenhängt." But this conclusion does not hold for Tatusia and Manis.

The Mandibulo-auricularis has been recorded as present in Choloepus, Myrmecophaga, Tamandua, and Dasypus. It has not been recorded in Bradypus, Tolypeutes and Chlamydophorus.

The Subcutaneus colli is very different in the two animals. In Tatusia there is a wide Platysma, but neither Sphincter externus nor internus exists. In Manis it consists of a Sphincter externus and a narrow band like Platysma, but there is no Sphincter internus.

In a 20 mm. embryo of Tatusia the facial and auricular muscles are innervated by the VIIth. The Subcutaneus colli is innervated by the R. colli VII and Ni. Cervs. ii and iii. In *Manis javanica*, according to Kohlbrugge, the facial musculature is innervated by the VIIth, and the Subcutaneus colli solely by cervical nerves, there being no R. colli VII. Kohlbrugge, who did not know the development of the muscles, was of opinion, on comparing the innervation of the Subcutaneus colli of Man and Manis, that either the R. colli VII of Man reaches the neck owing to disappearance of a cervical musculature, or that in Manis the territory which once belonged to Facialis musculature is taken over by spinal muscles and nerves. The latter theory, he said, is probably the true one. The developmental phenomena, however, in Tatusia and Manis show that in both animals the Subcutaneus colli is due to a backward spread from the hyoid segment. In the case of Tatusia there is thus a partial, in the case of Manis a total, replacement of VIIth nerve innervation of the Subcutaneus colli by nerve fibres of the cervical segments into which growth takes place.

The hyo-branchial skeletal structures of Manis and Tatusia consist of a basibranchiale with cornua hyalia and branchialia i. In Manis the ventral end of the C. hyale joins the C. branchiale i, and the ventral end of the latter the Basibranchiale, the structures forming a continuous whole. In Tatusia (*vide* Fawcett) the C. hyale separates into parts, and its ventral end articulates with the basibranchiale. The structures are thus simpler in Manis than in Tatusia.

The 1st branchial muscle-plate of Manis atrophies, and no Branchio-hyoideus muscle is formed. In Tatusia this muscle is developed, and is innervated by the IXth.

The Transversus hyoideus and Hyo-epiglotticus are developed in Tatusia, as parts of one muscle, and probably by separation of the posterior edge of the Transversus linguae. They are not developed in Manis. The Hyo-epiglotticus has been recorded as present in Myrmecophaga (Owen, Pouchet), and in Tamandua (Bender). In the latter it is stated to have "the same innervation as the ventral longitudinal muscles." In many Ungulata both Transversus hyoideus and Hyo-epiglotticus exist as separate muscles. In the pig they are developed from the Transversus linguae and, as in Tatusia, are innervated by a recurrent branch of the lingual portion of the XII.

The origin of the Cucullaris could not be observed in Tatusia. The significance of the phenomena in Manis is doubtful. They possibly indicate that it is developed from a 2nd branchial muscle-plate. But the development is not known in Monotremes, Marsupials, and Xenarthra. In the pig and in Erinaceus it is developed from the 1st branchial muscle-plate.

Both Sterno-mastoideus and Cleido-mastoideus are developed in Tatusia; but only the first-named in Manis, which has no clavicle. This feature is not peculiar to Manis, for in Bradypus, Myrmecophaga, and Tamandua, where the clavicle is rudimentary, there is no Cleido-mastoideus.

A Cleido-occipitalis is present in Chlamydophorus as a separate muscle. In Tatusia and Myrmecophaga a homologous muscle diverges from the cervical portion of the Trapezius and is inserted into the clavicle. The Occipito-humeralis of Manis is probably a homologous muscle. The method of insertion into the humerus is not uniform in Manidae, for Macalister stated that in *Pholidotus indicus* and *Manis multiscutatus* there is an intersection between it and the Deltoid.

The division of the Trapezius of Tatusia into anterior and posterior parts is not constant in Xenarthra, for in Myrmecophaga and Tamandua the muscle forms a continuous sheet.

In a 20 mm. embryo of Tatusia the Cucullaris group is innervated by the XIth, which receives a branch from N. Cerv. ii. In Manis (Kohlbrugge) the Trapezius is innervated by the XIth which receives a branch from N. Cerv. ii, and also by branches from Ni. Cervs. iii, iv, and v passing directly to the muscle; the Sterno-mastoideus is innervated by the XI and N. Cerv. ii. This additional innervation by branches of cervical nerves—more marked in Manis than in Tatusia—is in relation to the spread of the Cucullaris into cervical segments. There is a similar additional cervical innervation in the case of the Rectus cervicis of Tatusia, and it is the sole one in the case of the Sterno-thyroideus of Manis (*vide supra*).

The pharyngeal muscles in both Tatusia and Manis consist of a Stylo-pharyngeus, Constrictor pharyngis, and Palato-pharyngeus. In Tatusia the Stylo-pharyngeus and Constrictor pharyngis form one muscle, which consists

posteriorly of constrictor fibres, and anteriorly of longitudinal fibres passing into the soft palate. In Manis the Stylo-pharyngeus passes towards the wall of the pharynx, ventral to the lower edge of the Constrictor pharyngis.

The Palato-pharyngeus is developed on the inner side of the Stylo-pharyngeus and Constrictor pharyngis, and forms a longitudinal muscle. This is preserved in Manis, whilst in Tatusia, apparently, the posterior part of the muscle disappears and the anterior part forms a curved transverse muscle, passing from the wall of the Eustachian tube to the soft palate.

The Epiglottic cartilage in Tatusia is developed in the epiglottis as a posteriorly concave structure, the ventral edges of which are attached to the dorsal edge of the thyroid cartilage (figs. 29, 30). The epiglottic cartilage in Manis is similar in shape, but differs in that its ventral edge is attached to the Basithyroid (fig. 54). But this condition is not constant in Manidae, for Albrecht stated that in *Manis gigantea* its lower edge is attached to the upper edge of the thyroid cartilage.

Investigation of the first stage of Manis (fig. 34) shows that the Aditus laryngis is bounded by the Plicae laterales[1]. In the next stage (fig. 37) the Plicae inferiores[2] have developed, and bound the Aditus. Their anterior ends are close to, but do not join, the back of the epiglottis. Finally, the Plicae laterales overtop the Plicae inferiores, the position of which is now relatively more ventral. The changes in Tatusia are similar (figs. 30, 31), but the first stage had been passed in the 10 mm. embryo.

In this respect Manis and Tatusia resemble the pig and rabbit, and differ from Dasyurus, in which the Plicae inferiores have their permanent position from the time of their first development. The difference is perhaps, as previously suggested, related to the shorter period of intra-uterine life in Dasyurus.

The Plicae inferiores do not fuse with the epiglottis and hence do not become secondary ary-epiglottic folds. In this respect Manis and Tatusia resemble Dasyurus and differ from the pig and rabbit in whom fusion occurs. The condition in adult Xenarthra is variable, e.g. in *Tamandua didactyla* the Plicae inferiores fuse with the epiglottis (Göppert), whilst in *Tamandua tetradactyla* they do not (Bender).

In Manis determination of the segment of origin of the thyroid cartilage is possible. The superior laryngeal nerve passes into the larynx posterior to the 4th gill-cleft, between that and the postbranchial body, i.e. in the 3rd branchial segment. The thyroid cartilage is developed subsequently and at the same antero-posterior level, and is consequently a 3rd branchial structure. It is not added to by any skeletal structure in front.

The corresponding early stages of Tatusia were not available.

In Manis there is only one superior laryngeal nerve. In Tatusia the nerve enters the larynx by two branches (figs. 13, 23, 24)—an anterior and a posterior.

[1] Plicae laterales (Symington), Partes laterales epiglotticae (Göppert).

[2] Plicae inferiores (Albrecht), Plicae ary-epiglotticae (Göppert).

The latter, in the 20 mm. stage, enters above the superior border just in front of the junction of the C. branchiale i with the thyroid cartilage—in the same position as the single nerve in Manis. It is therefore possible that in Tatusia there are 2nd and 3rd branchial nerves, but investigation of earlier stages is necessary to determine the matter. It may be added that this entry of the superior laryngeal nerve by two branches is not peculiar to Tatusia; it also occurs in Bradypus and Myrmecophaga (Dubois).

In regard to these questions it is interesting to recall the statement of Dubois, made in 1886. "The N. laryngeus superior represents the 3rd branchial nerve," and "it must remain an open question whether the 2nd branchial nerve has disappeared or whether it is fused with the N. laryngeus superior, and that its anterior branch so frequently present in Marsupials and Placentalia represents it."

It follows from the above that the thyroid cartilage of Tatusia may turn out to be either a 2nd branchial skeletal structure, as suggested by Fawcett, or a 3rd branchial structure, as in Manis; or the result of fusion of 2nd and 3rd branchial structures, as in Trichosurus.

The N. laryngeus recurrens passes into the larynx dorsal to the cricothyroid articulation in both Tatusia and Manis, and also in Tamandua (Bender). In this relationship these animals agree with other Eutheria, and differ from Monotremes and Marsupials in which the nerve passes forward ventral to the articulation.

The cricoid and arytenoid cartilages in Tatusia and Manis are formed as a continuous whole. On separation, the arytenoid cartilages are found to be connected by a dorsal bridge. This interarytenoid bridge does not persist in either animal, e.g. in Tatusia it is present up to the stage of 20 mm. but is atrophied in one of 30 mm. The bridge is generally absent in adult Xenarthra, but is present in *Dasypus gymnurus* (Albrecht). No case has been recorded in adult Xenarthra in which the interarytenoid bridge persists as a separate C. interarytenoidea s. intermedia. In this respect Xenarthra present a marked contrast to Marsupials and Monotremes. In Manis the primordium of the laryngeal muscles is formed as a postbranchial structure separated off from the primordium of the Constrictor oesophagi, migrates forward into the laryngeal region, and there develops into the Laryngeus dorsalis, Laryngeus ventralis, and Dilatator laryngis. In this Manis agrees with the pig. The corresponding stages of Tatusia were not available.

Knowledge of the laryngeal muscles in Xenarthra and Manidae is but slight. Incomplete accounts were given by Murie of Tolypeutes, and by Albrecht of *Dasypus septemcinctus, D. gymnurus, D. villosus, Bradypus didactylus,* Myrmecophaga, and *Manis gigantea.* The best description is that by Bender of Tamandua. The conditions found in Tatusia and *Manis javanica* may be compared with these. It would appear that (1) the Dilatator laryngis s. Crico-arytenoideus posticus always remains single. It does not separate into inner and outer portions as in Marsupials. (2) The Laryngeus dorsalis s. Inter-

arytenoideus passes from the C. arytenoidea to a dorsal median raphé. (3) The Laryngeus ventralis is very variable in subdivision.

(*a*) A Crico-arytenoideus lateralis is developed in *Tatusia novemcincta*, *Dasypus septemcinctus*, Tamandua, and also, judging from Albrecht's figures, in *Dasypus villosus* and Myrmecophaga, but not in *Manis javanica*. It is not known whether it is developed in *Manis gigantea*, *Bradypus didactylus*, and *Dasypus gymnurus*.

(*b*) The Thyro-arytenoideus remains single in *Manis gigantea*, *Dasypus septemcinctus*, and *Bradypus didactylus*. It becomes more or less separated into Thyro-arytenoideus superior and inferior in *Dasypus gymnurus*, *D. villosus*, Myrmecophaga, Tamandua, *Tatusia novemcincta*, and *Manis gigantea*.

The above recorded observation and discussion suggest that the following features characterise the cranial muscles of Xenarthra. (1) A Pterygo-tympanicus is generally present (it has not been recorded in Myrmecophaga and Chlamydophorus). (2) A homologue of the Detrahens mandibulae is perhaps present in Tamandua, Dasypus, and Tolypeutes. (3) A Mandibulo-auricularis is commonly present. (4) The Interhyoideus arises from the C. hyale in Tolypeutes and Chlamydophorus. Its origin extends up to the skull in other genera, and the muscle may undergo subdivision into upper and lower portions. (5) The Dilatator laryngis s. Crico-arytenoideus posticus remains single. (6) A Sterno-mandibularis is present. It is formed by attachment of the Digastricus anterior to the transverse aponeurosis of the Interhyoidei and rotation of the muscle into a longitudinal position, the separation of a Sterno-hyoideus superficialis from the Sterno-hyoideus and attachment of its anterior end to the transverse aponeurosis. The resulting primary condition present in Bradypus, Choloepus, and Tolypeutes, is a Sterno-mandibularis with an intersection. The intersection is lost in other genera and the muscle becomes a continuous one.

The characteristics of the cranial muscles of Manidae are: (1) Fusion of the Sterno-hyoideus and Hyo-glossus, forming a Sterno-glossus. (2) Backward extension of the Sterno-glossus and Sterno-thyroideus in the thorax. (3) Backward extension of the Genio-hyoideus, and in less degree of the Transversus linguae, forming ventral and dorsal inner sheaths for the Sterno-glossi. (4) Backward extension of the Intermandibularis, with attachment of its posterior part to the base of the skull, forming an outer sheath for the fore part of the Sterno-glossi. (5) In *Manis javanica*, and possibly also in *Manis tricuspis* and *macrura*, backward extension of the Interhyoideus, forming an outer sheath for the hinder part of the Sterno-glossi. (6) Transformation of the Tensor tympani and Digastricus anterior into protractors of the hyoid bar and salivary gland. (7) Formation of both Pterygo-tympanicus and Tensor veli palatini. (8) Atrophy of the Pterygoideus internus. (9) Formation of a Zygomatico-mandibularis. (10) Formation of an Occipito-humeralis. (11) Non-formation of a Cleido-mastoideus. (12) Formation of a Mandibulo-auricularis. (13) The Stylo-pharyngeus forms a Dilatator pharyngis. (14) Non-formation of a

Branchio-hyoideus. (15) Non-formation of a Transversus hyoideus and Hyo-epiglotticus.

Manidae thus possess the characteristic Xenarthric feature of a Pterygo-tympanicus, but not that of a Sterno-mandibularis, and there are many secondary features correlated with the great development of the tongue and the absence of a clavicle.

I have the pleasure of thanking Prof. Fawcett for the loan of the sections of Tatusia, and Prof. de Lange for the loan of the sections of Manis and of Erinaceus.

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SYNONYMS

Interhyoideus. Stylo-hyoideus, Stylo-hyoid, Stylo-hyoïdien. Hyrtl, Macalister, Chaine, Burne (Chlamydophorus). Toldt (Manis).

Digastricus, hintere Bauch. Toldt (*Dasypus villosus*, Tatusia, *Bradypus tridactylus*, Tolypeutes).

Ventre postérieure du digastrique. Chaine (*Dasypus villosus*, Tatusia, *Bradypus tridactylus*).

Venter posterior M. digastrici. Bijvoet (*Bradypus tridactylus*).

Portion of Glossovaginalis superficialis arising from bulla tympanica s. Stylo-hyoideus. Ehlers (Manis).

Interhyoideus dorsalis. Mastoideo-hyoideus. Schulman (Choloepus, Tamandua). Stylo-hyoideus. Owen (Myrmecophaga). Toldt (Tamandua). Stylo-mastoideus. van Kampen (Tatusia). Stylo-mastoïdien. Pouchet (Myrmecophaga).

Interhyoideus ventralis. Styloideus. Schulman (Choloepus Tamandua). Cerato-hyoideus. Owen (Myrmecophaga). Stylo-hyoïdien. Duvernoy and Pouchet (Myrmecophaga). Mylo-hyoideus, superficial layer. Toldt (Tamandua).

LIST OF FIGURES

The figures are taken from sections cut in a frontal plane except in the case of Nos. 29–31, which are from transverse sections. In any series from an embryo the one with the lowest number denotes the uppermost, or the most anterior, section drawn.

Tatusia novemcincta. Figs. 1–31

Figs 1–5 Embryo 10 mm. vertex-breech length.
Figs. 6–16. Embryo 12 mm. vertex-breech length.
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Figs. 29–31. Embryo 30 mm. vertex-breech length.

Manis javanica. Figs. 32–63.

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Figs. 37–39. Embryo 8·5 mm. (B) vertex-breech length. (This embryo, though of the same size as (A), is slightly more advanced in development.)
Figs. 40–44. Embryo 10 mm. vertex-breech length.
Fig. 45. Embryo 13 mm. vertex-breech length.
Figs. 46–53. Embryo 14 mm. vertex-breech length.
Figs. 54–58. Embryo 18·5 mm. vertex-breech length.
Figs. 59–63. Embryo 21 mm. vertex-breech length.

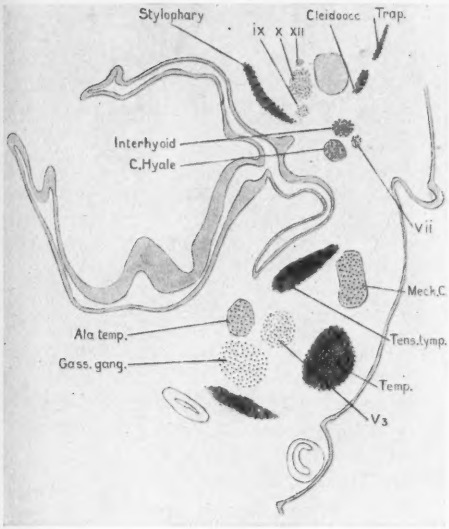
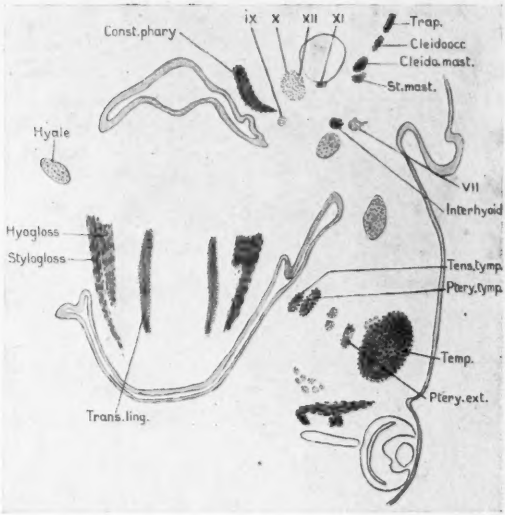


Fig. 1



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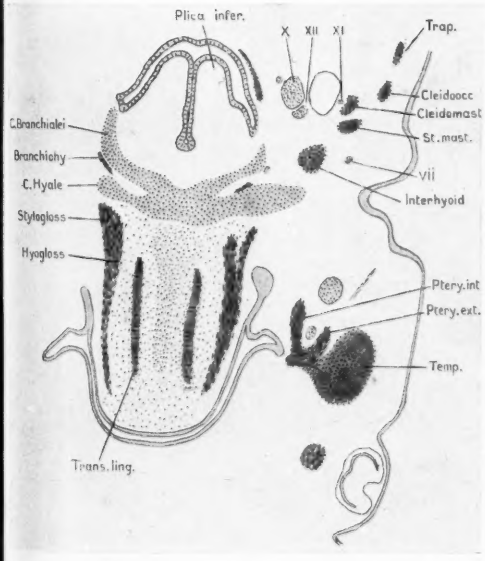

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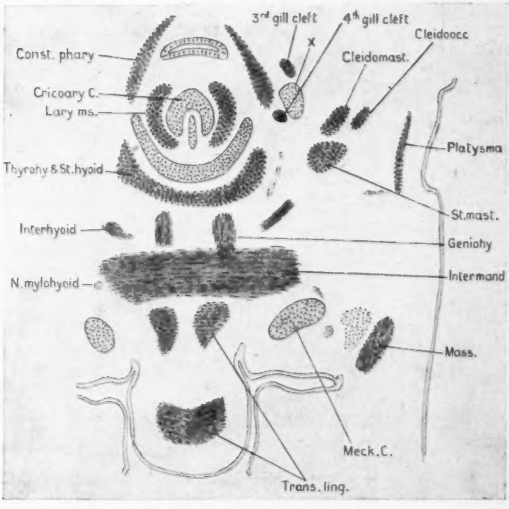

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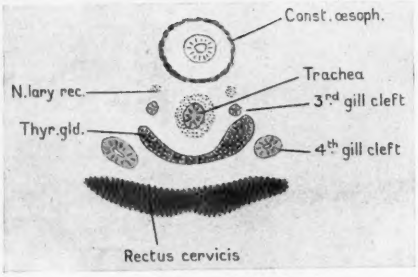

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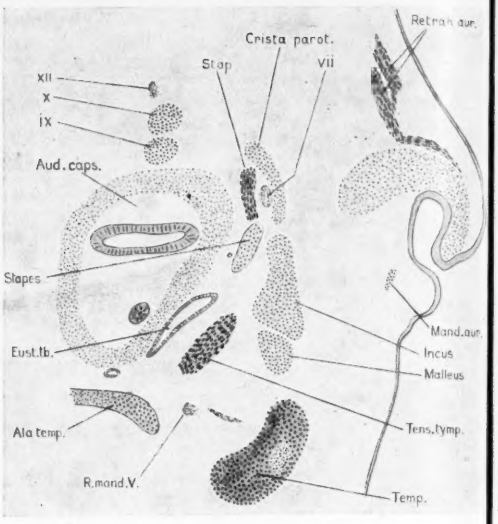

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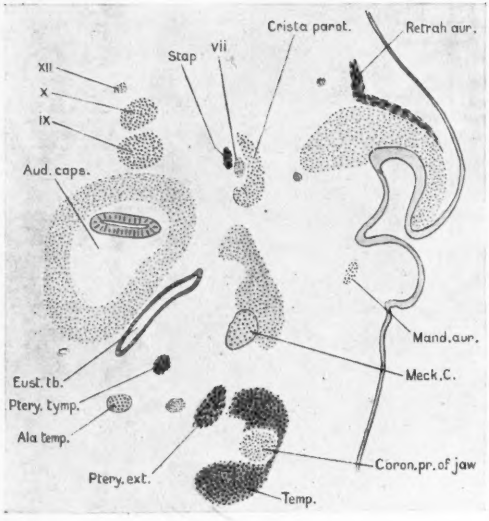

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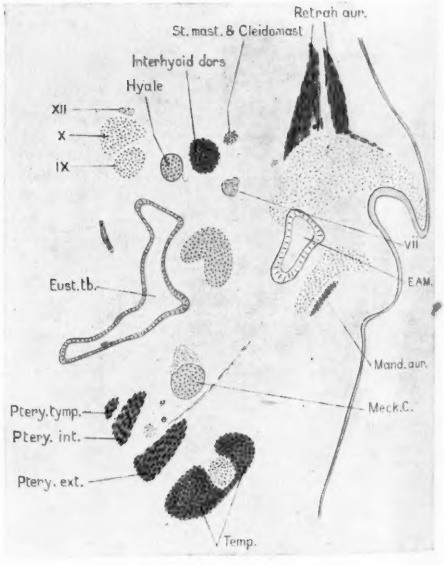

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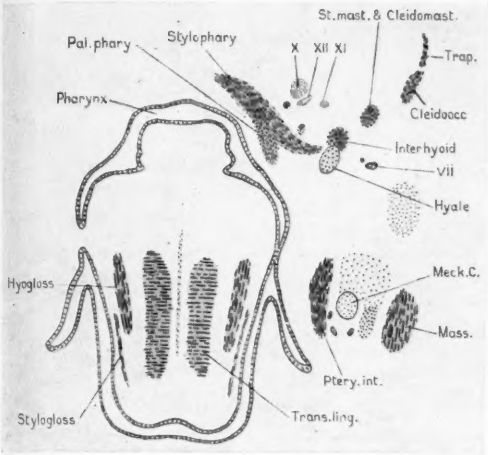

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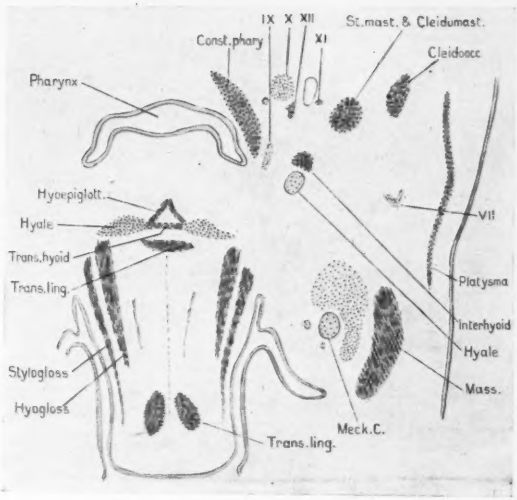

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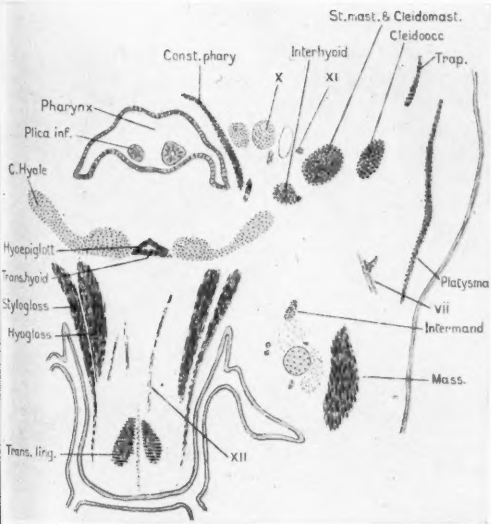

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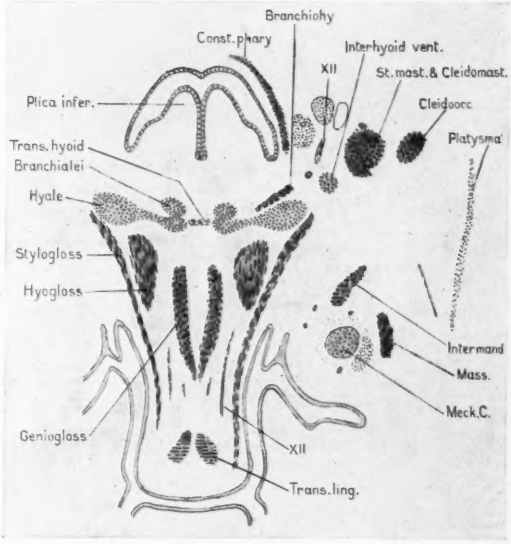

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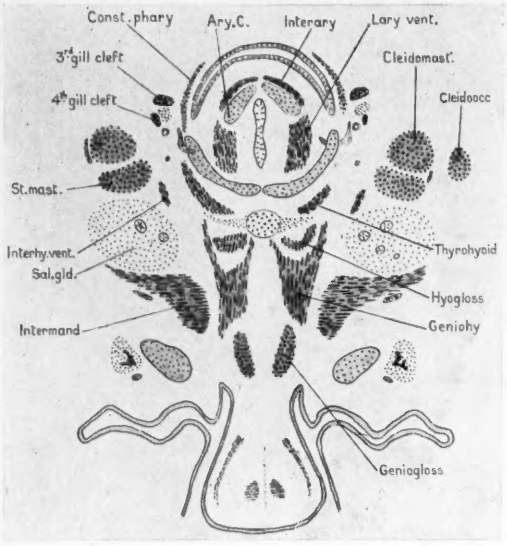

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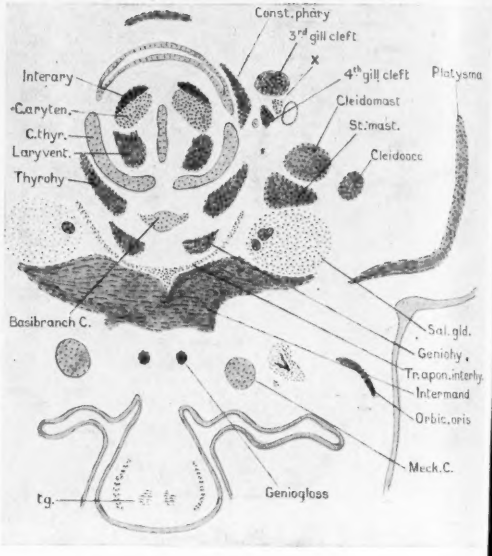

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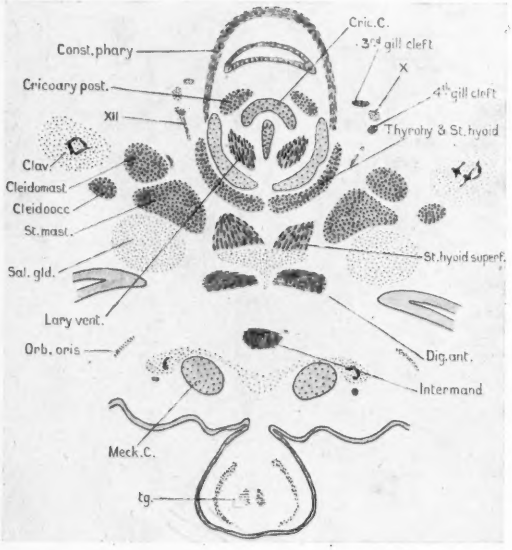

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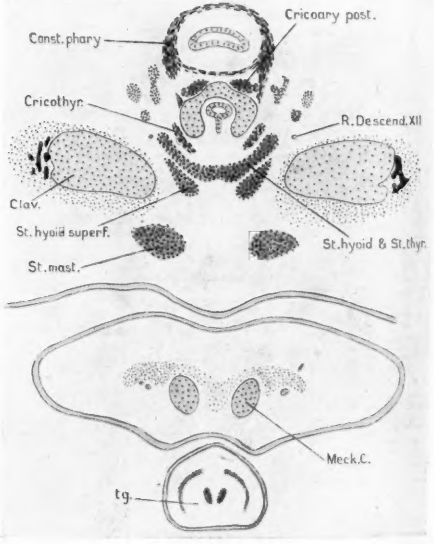

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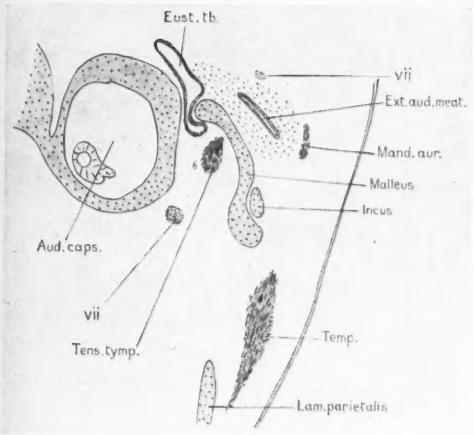

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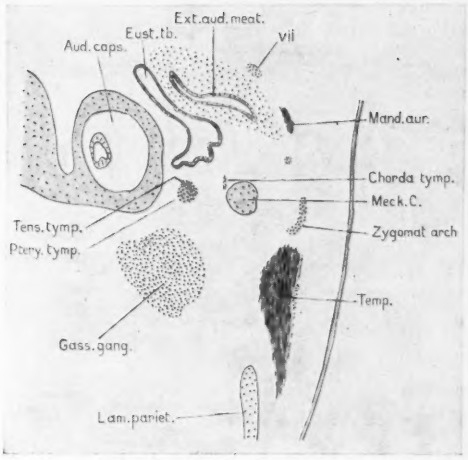

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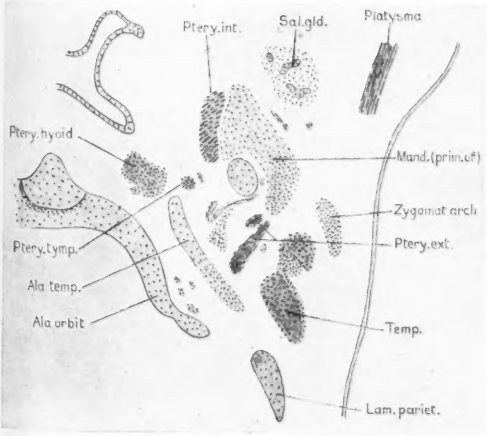

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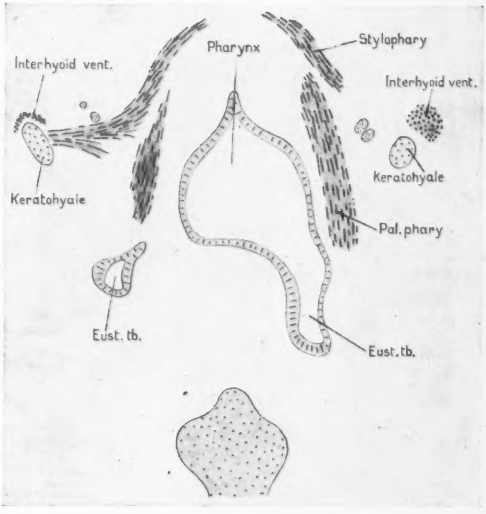

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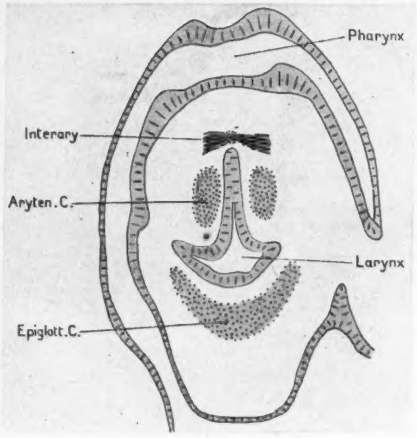

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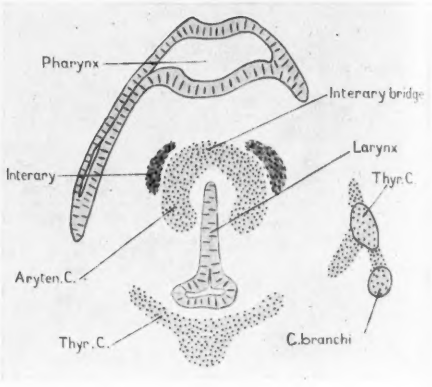

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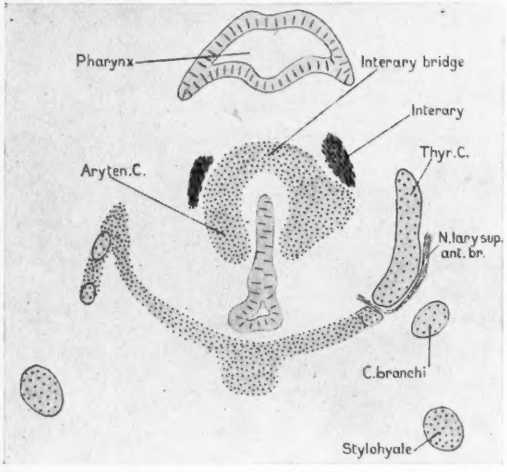

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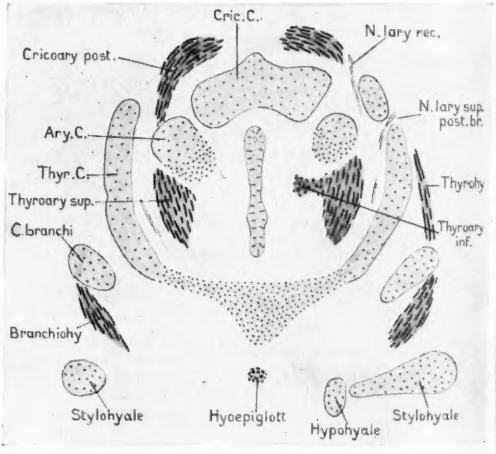

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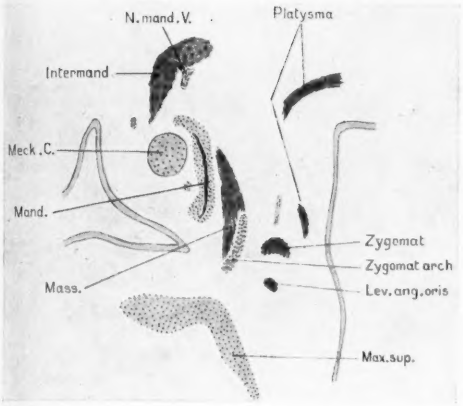

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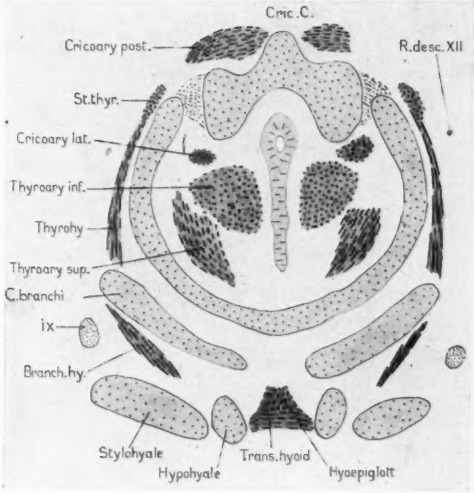

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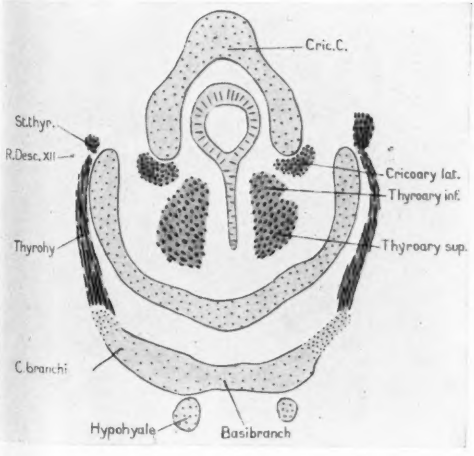

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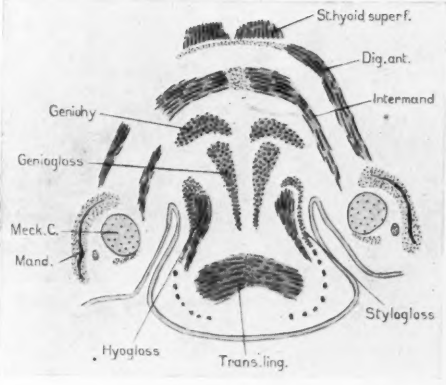

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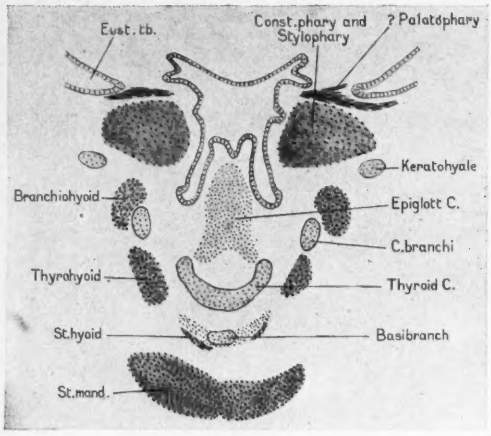

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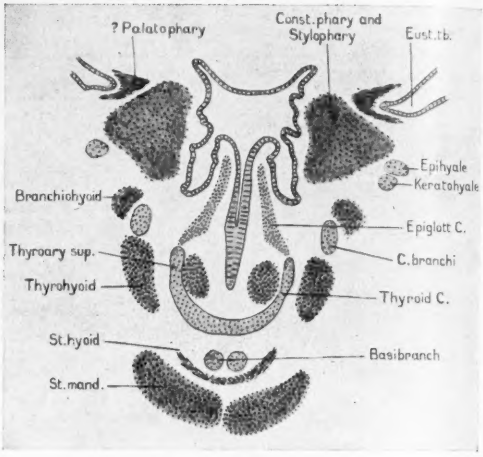

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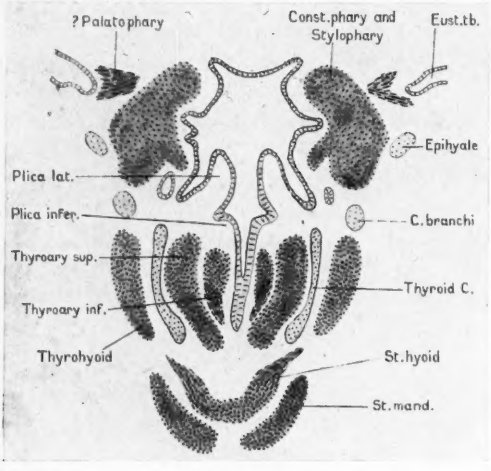

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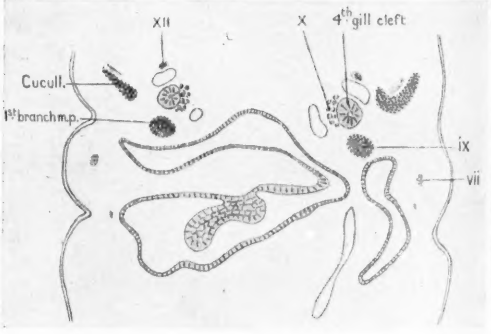

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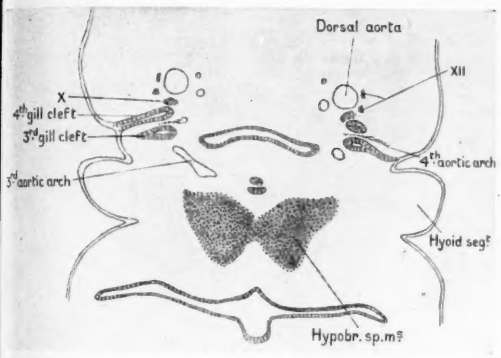

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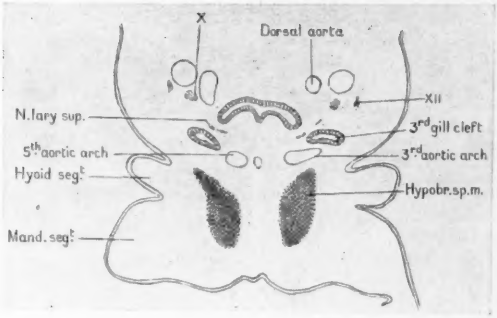

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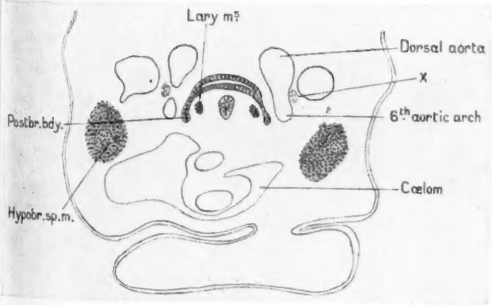

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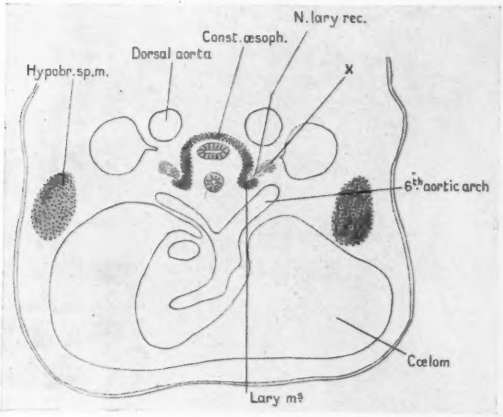

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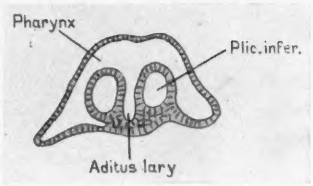

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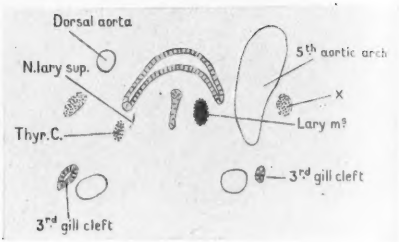

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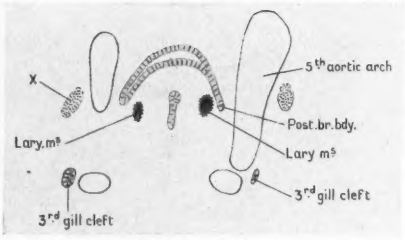

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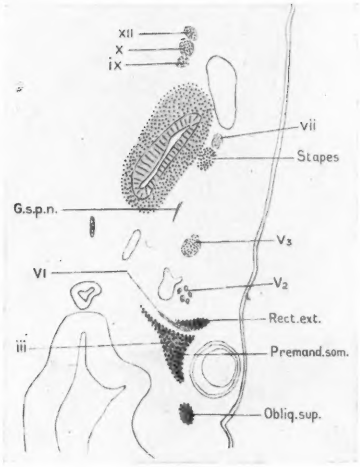

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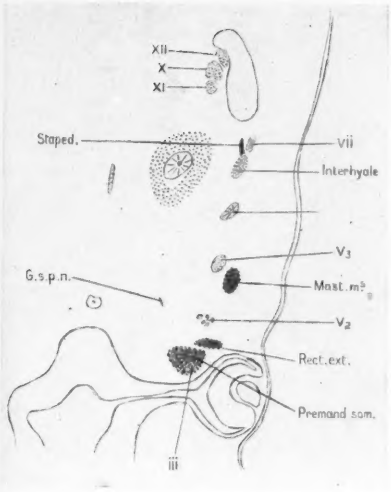

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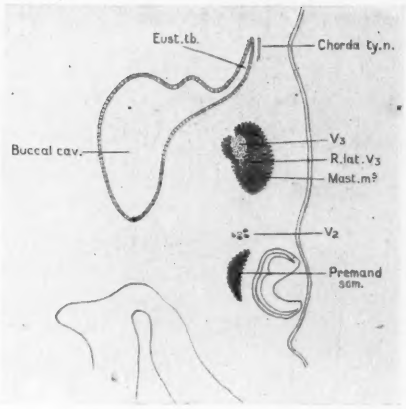
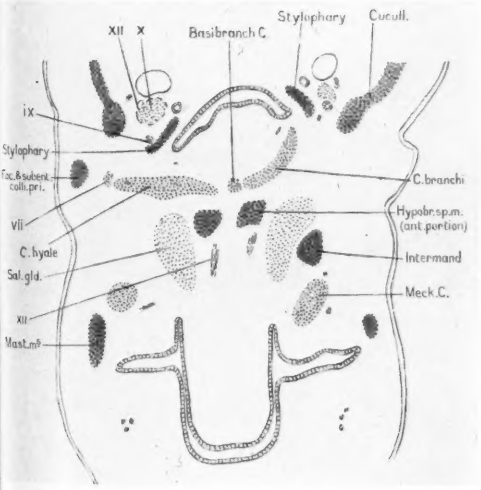


Fig. 42



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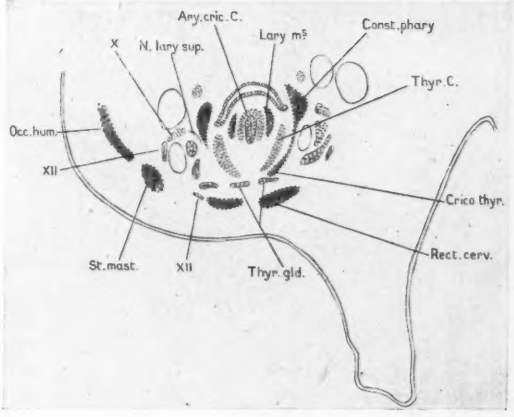

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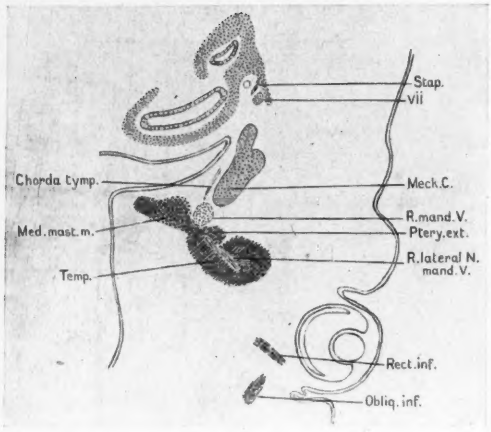

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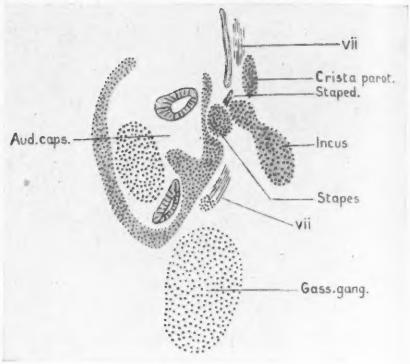

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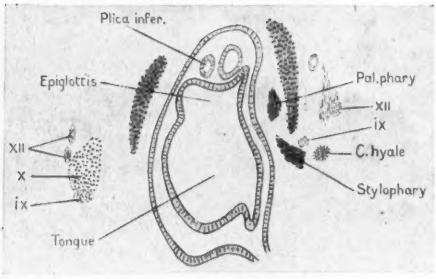

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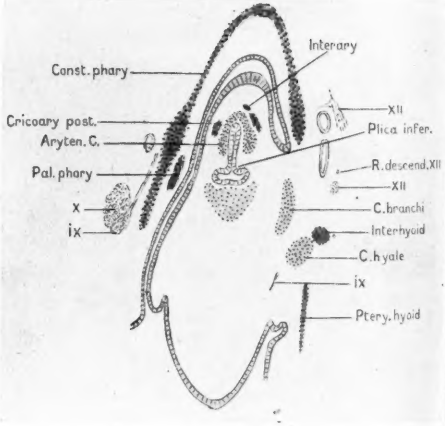

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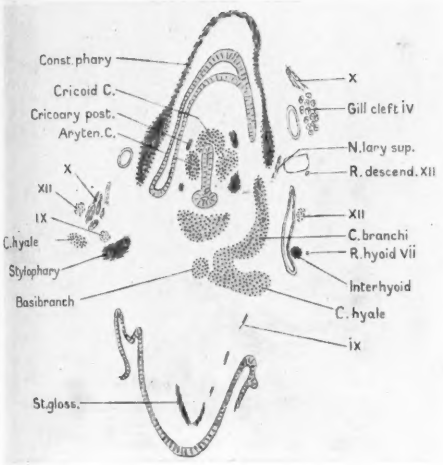

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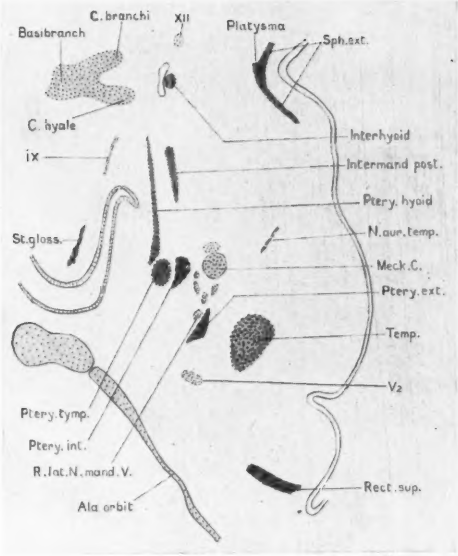

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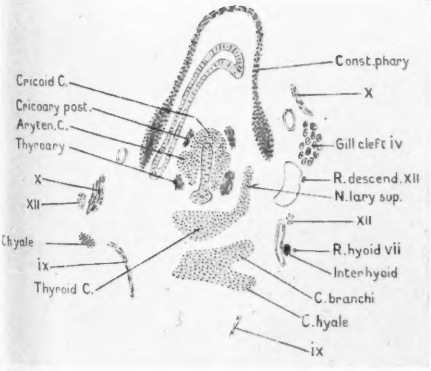

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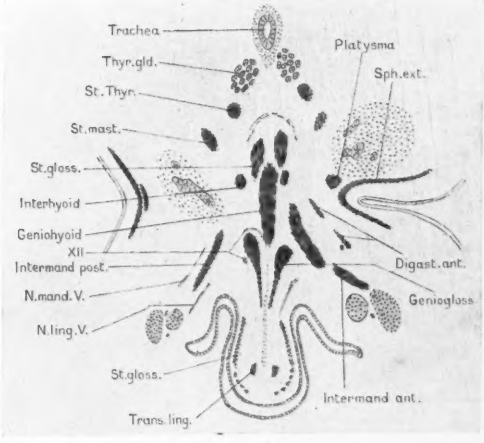

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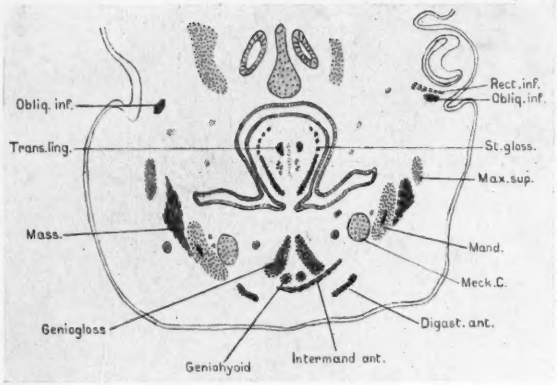

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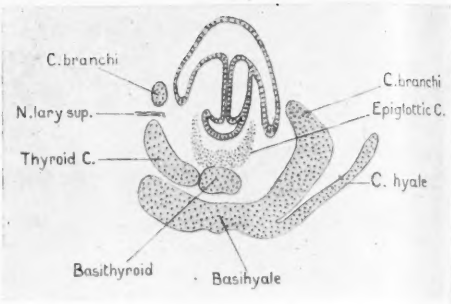

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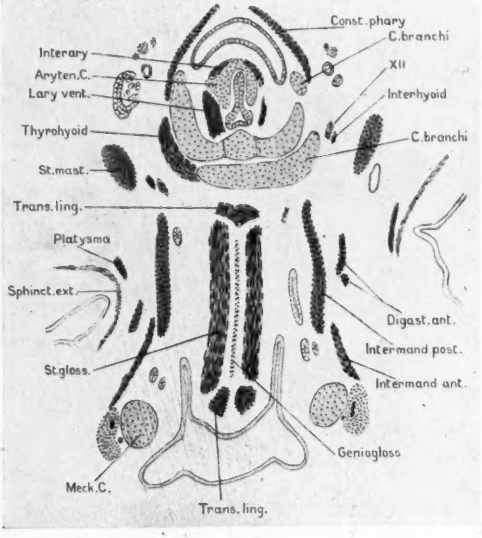

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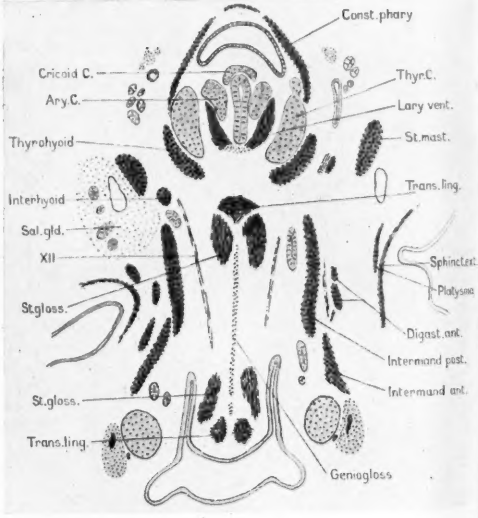

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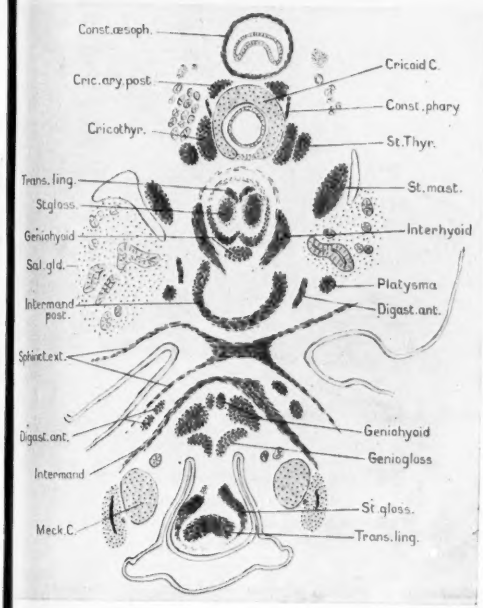

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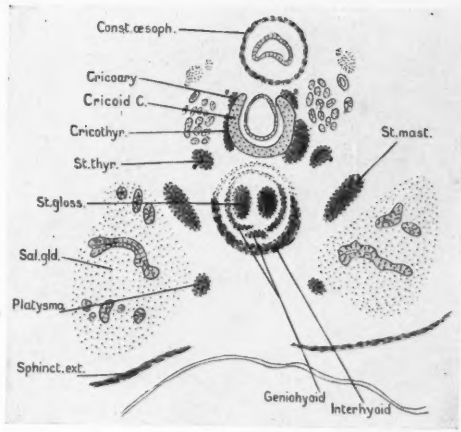

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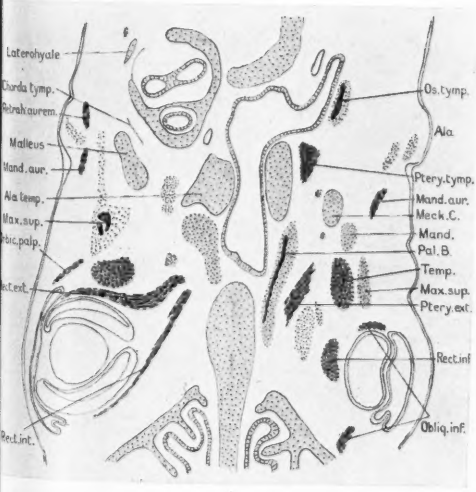

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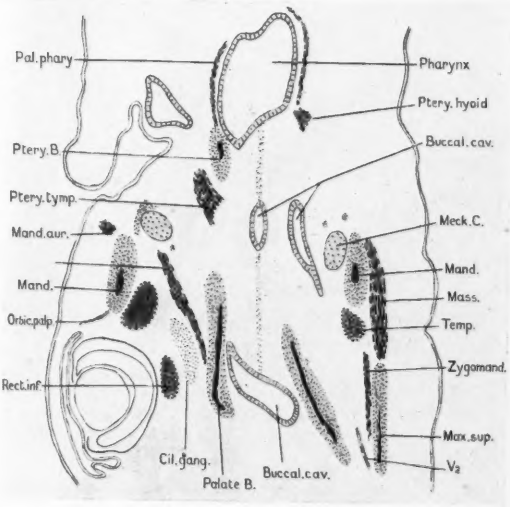

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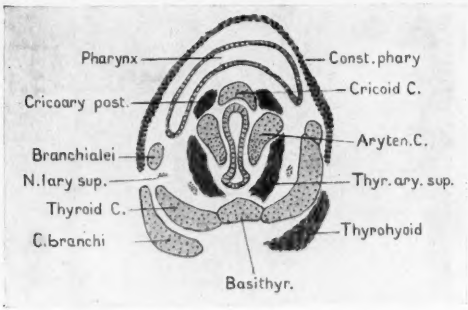

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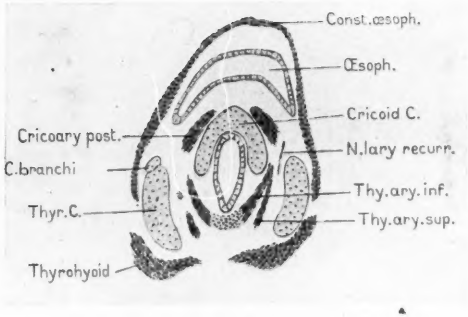

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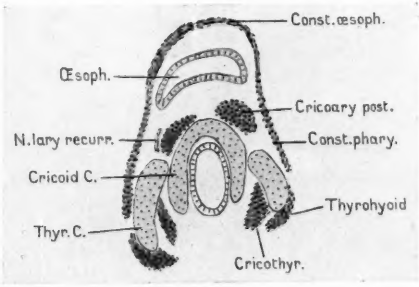

Fig. 63

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THE EFFECT OF MACERATION AND DRYING UPON THE LINEAR DIMENSIONS OF THE GREEN SKULL

By T. WINGATE TODD, F.R.C.S.
Western Reserve University, Cleveland, Ohio.

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INTRODUCTION

In a former and larger work (8) I have discussed in a preliminary manner the influence of drying upon the linear dimensions of the cranium. When one attempts to obtain an approximation of true cranial capacity from dimensions of the living skull one must make corrections for certain errors. Of these the error resulting from estimation of the thickness of the soft tissues will not concern us at the moment. Since all really serviceable computations of cranial capacity made strictly in accordance with statistical theory have been based upon dimensions obtained from dried specimens it is plainly necessary to form some idea of the shrinkage taking place in all the basic dimensions as a result of drying. It may be objected that estimation from living values does not permit an approximation close enough to allow one to hope for a greatly increased accuracy even if this small correction is obtained because there are many factors still at work limiting the probable accuracy in individual cases. We have already mentioned the superficial soft parts. In addition there are the volume of the dura and the thickness of the skull bones as well as peculiarities in conformation of the head itself. It is not beyond hope that in time all these sources of error may be minimised. Some work has already been done upon the thickness of the soft parts; I have taken up in considerable detail the problem of the dura volume (8): it is possible that eventually we may have some fair guide to the probable average thickness of the skull bones: variations in the conformation of the head do not inject a very considerable error even for

the individual except in rare instances which are usually obvious. As far as racial values of the dried skull are concerned it has been shown beyond a doubt that even with present limitations an accuracy of computation of capacity can be obtained as great as or greater than that resulting from direct capacity determination by an experienced observer. This in itself encourages the expectation that with proper corrections it may soon be possible to obtain a result of at least comparable accuracy from living measurements. After all it is the anatomy of the race and particularly of the living race that will mostly concern us in the future. No further justification is needed for the investigation of problems in living anatomy.

If there is to be any success in this newer field of living anatomy now rendered possible by clinical methods devised in recent years the work must be done in the Hospital and Medical School where the same individual is under observation both before and after death, rather than in the Museum or the Institute remote from the Clinic. In very many problems such as that under consideration, namely cranial capacity, the Anatomical Department is, up to the present, directly responsible for the paucity of organised data, for surely there, if anywhere, a wealth of material has passed to final extinction, serving merely to equip students in traditional manner with the rudiments of the subject. The increasing difficulty in obtaining anatomical material makes it increasingly evident that material must be utilised to greater advantage and the claim really made good that it is the introduction to a broader, essential and vital anatomy of the quick rather than merely of the dead.

HISTORICAL SURVEY

So far as I am able to discover there has been no work done upon the initial shrinkage of bones in drying. It is true that Welcker, Broca and Pearson have made observations upon the effect of moisture and of subsequent drying upon the dimensions of the previously dry skull and of the femur. This is not exactly the same problem and although it is a valuable addition to our knowledge it does not give us the confidence of first hand information upon the change consequent upon transformation of green bones into dry bones.

Pearson's work (7) refers to the femur and as such does not come directly within our purview. Welcker published his investigation upon the skull in a volume which unfortunately is inaccessible to me (9) but I have beside me the study of Welcker's observations and deductions made by Broca (1), a study which bears the ear-marks of all Broca's faithfulness to detail and fairness in statement when in the position of an opponent. Broca used solely dried skulls which he subjected to varying degrees of humidity and to total immersion in water. Welcker had certainly observed green skulls for he made the statement that if a green skull be bisected and then macerated the two halves no longer correspond. With this observation I do not find myself in agreement. All our skulls are bisected green and then macerated by Leonhart's live steam method. There have now passed through our hands some nine hundred skulls

and not once have we found a specimen in which the two halves do not exactly correspond at all stages of drying. I can only conclude that the skulls referred to by Welcker were macerated by a very imperfect method, a view which appears to have been shared by Broca (1, p. 68).

According to Broca, Welcker found that after three successive days' soaking in water an adult human skull undergoes the following average increases in cranial dimensions: length 0·4 mm.; breadth 0·7 mm.; basio-bregmatic height 0·7 mm. This, of course, is practically negligible as most series of measurements are by the nature of the instruments used, not correct to less than 0·5 mm., and ill accords with Welcker's own statement regarding the non-correspondence of two halves of a skull macerated after bisection, unless indeed my contention be allowed that a crude method of maceration was employed.

Broca himself found an increase of some 30, 40 or even 50 c.c. in capacity as the result of soaking the skull whereas the linear extensions given by Welcker increase the capacity by only 18·98 c.c. on Broca's method of computation. Considering the delicacy of measurement of so relatively slight a change in dimension Broca suggests that perhaps an error of 0·3 or 0·4 mm. may have crept into Welcker's estimates and that this correction would bring the results of the two investigations into harmony.

In my previous work (8) I have endeavoured to ascertain the shrinkage of ten male White skulls as the result of drying for a period of more than a month in the dry atmosphere of our steam-heated Museum. Having allowed for the instrumental error my results are the following: length 2·3 mm.; breadth 2·25 mm.; auricular height 1·8 mm. This is a very great increase upon the changes determined by Welcker. The question which therefore presented itself to me was whether the initial shrinkage is so much greater than the extension obtained by soaking the dry skull or whether more delicate instruments would show that I had exaggerated the amounts. I have already shown that this shrinkage in a skull of about 1500 c.c. capacity amounts to a difference of 47 c.c. which is within the range anticipated by Broca and accords very well with my own direct determinations. Nevertheless the problem seemed worthy of a more intensive study and it is the result of this study which I now present.

TECHNICAL METHODS AND THEIR CONTROL

In a piece of work requiring such accurate measurement the instruments used must be very carefully tested. The preliminary investigation which I have already published showed me the vital necessity of instruments with a smaller error than I was then using (8). For holding the skull and measuring the auricular height I have employed a modification of Ranke's Craniophor (Pl. I) and for measuring greatest length, Pearson's Blocks (Pl. II), both instruments being made in the laboratory by our Mr Cherney. The instruments are mounted upon millimetre paper fixed to a drawing-board by Martin's

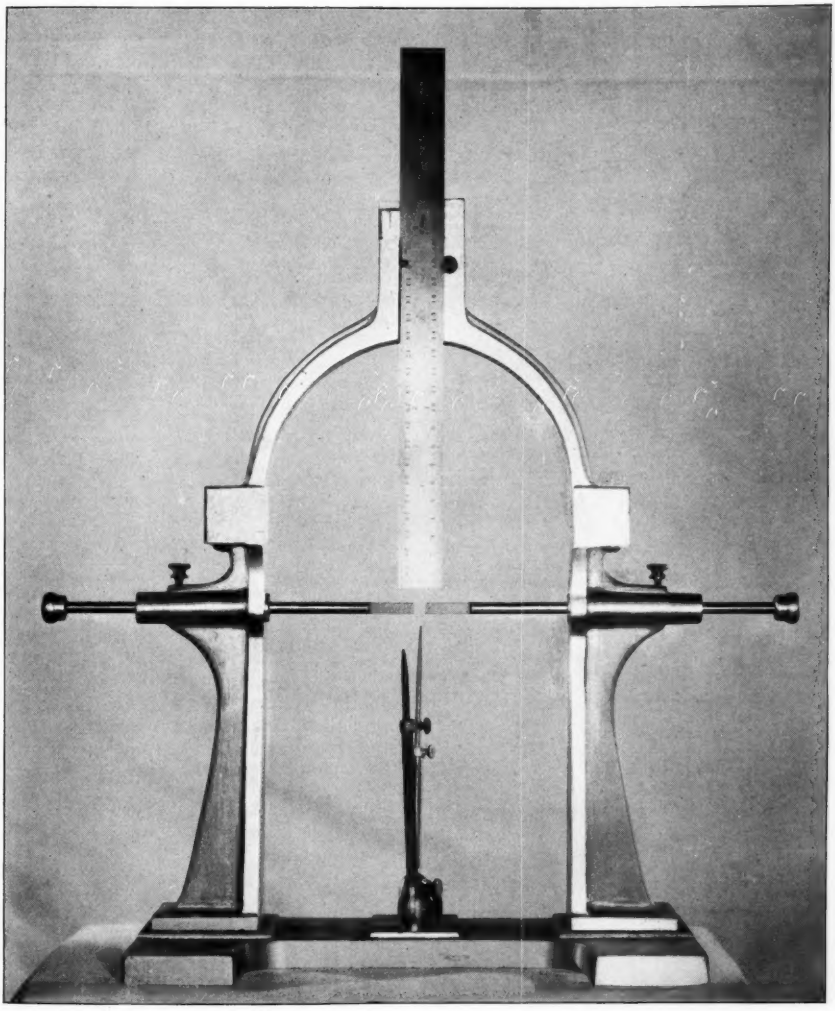

Fig. 1. The Reserve Craniostat as seen from the front.

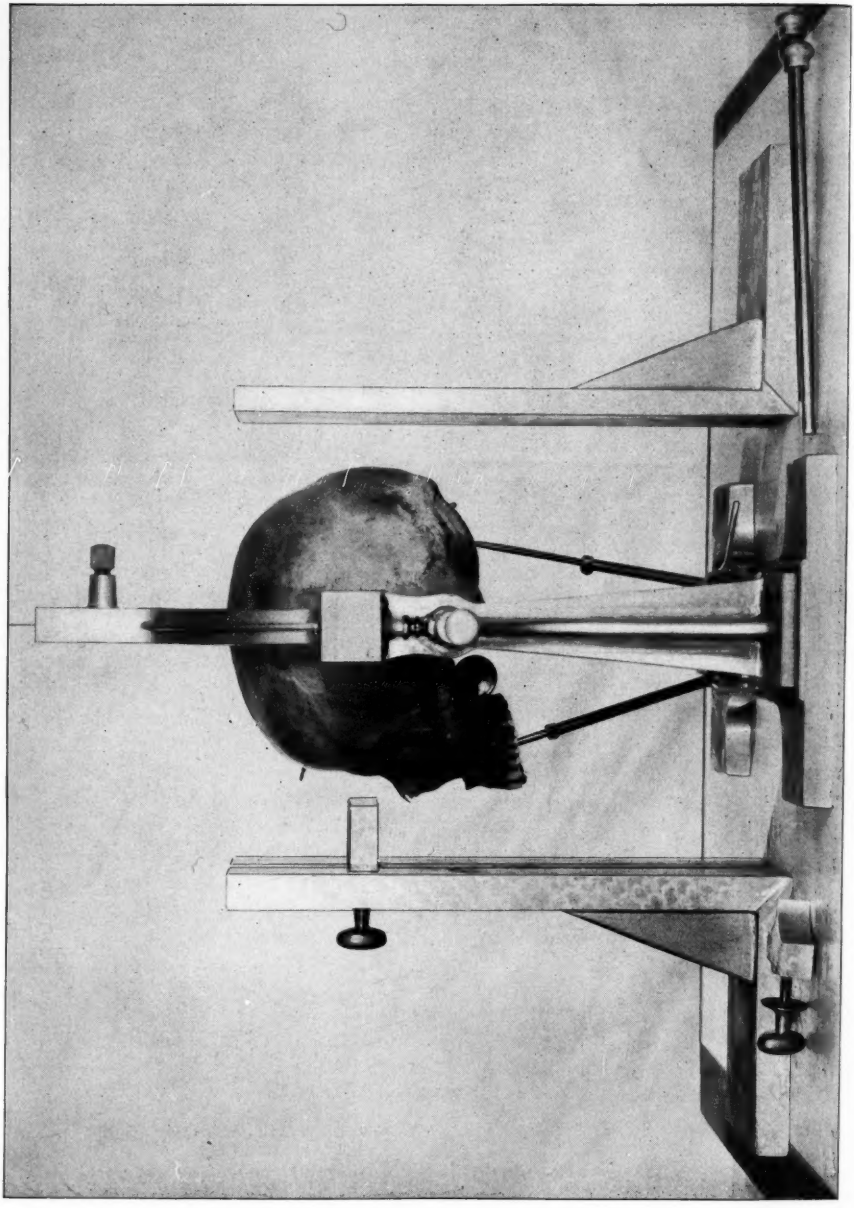

Fig. 2. Reserve Craniostat and Cambridge (Pearson's) Blocks mounted upon millimetre paper. By the former the auricular height is determined. The Blocks give greatest length. In this illustration the front block has mounted upon it the flat aluminium projection for determining greatest length including superciliary ridges (see Fawcett (2)).

celluloid cement (6, p. 32) and varnished with the same material. This millimetre paper has been carefully checked up with a Flower's craniometer manufactured by Aston and Mander, and with Martin's Gleitzirkel made by Hermann. The skull is oriented in the Frankfort plane by the aid of a Spengler's pointer (Horizontiernadel) and both glabellar length and greatest length including superciliary ridges read off with the assistance of the blocks. The auricular height is taken twice, first with the skull mounted on the knife edge supports (see fig. 1) and next mounted on the rounded rods. (These rods may be seen lying on the base in fig. 2.) By this double measurement of each dimension I have sought to eliminate gross errors of reading and to minimise fine ones of technique. The breadth is taken as usual with Flower's craniometer and the site of greatest breadth recorded. After very careful checking, the demonstration of which need not be entered into here, I am disposed to accept the recorded measurements without further correction such as I felt compelled to adopt in my earlier work (8). The saw-cut needed for the bisection of the skull when green does not concern us since the initial measurement of breadth in this investigation is obtained subsequent to that operation.

The last series of skulls to pass through the macerator for the year 1922, twenty-four in all, I have measured within twelve hours after emergence from the macerating tank (some delay being advisable to permit of draining), and at intervals of a week thereafter. The work started on May 12 and continued until July 14. On August 18 and 19 I repeated all measurements and am therefore able to state the shrinkage occurring during this period. None of the skulls has been subjected to the dry steam heat of the building during the Spring months so that one is able to compare results with those of the former research carried out during the Winter. The drying influence has been the ordinary Summer heat with the normal fluctuation in humidity. The skulls fall into two series, a larger one of twenty specimens emerging from the macerator on Tuesdays and a smaller one of four skulls taken from the macerator on Fridays. It is therefore in the larger series that we are enabled to study the effect of the weekly changes in heat and humidity.

In order to abbreviate this report I do not propose to set out in full the measurements and detailed observations which this work has demanded but rather to prepare summaries of the results attained.

GENERAL FEATURES OF SHRINKAGE OF THE SKULL IN DRYING

In his consideration of the figures presented in this section the reader must recognise that the shrinkage being investigated is that of the macerated skull in drying. It is not the alteration in dimensions consequent upon the change from the green to the dried macerated skull.

Of the twenty-four skulls employed, there are eleven male Whites, four female Whites, six male Negroes and three female Negroes, this being the random sample of the last maceration for 1922. Table I gives the average

Table I. *Average final dimension and average shrinkage in mm. with percentage of latter on former.*

Row	No. of skulls	Sex and Stock	Length	Shrinkage	%	Breadth	Shrinkage	%	Auric. height	Shrinkage	%
1	11	M. W.	186·3	1·27	0·68	145·3	1·45	1·01	116·6	1·41	1·21
2	4	F. W.	174·1	1·25	0·72	132·6	1·87	1·41	111·6	1·50	1·34
3	6	M. N.	187·1	2·17	1·16	139·3	2·08	1·49	111·1	1·54	1·39
4	3	F. N.	178·2	1·50	0·84	133·5	1·83	1·37	110·4	1·75	1·58
5	24	Total	183·2	1·52	0·83	140·2	1·73	1·23	113·6	1·50	1·32
		Measurements with "old apparatus" (see (8)) corrected.									
6	10	* M. W.	181·7	2·3	1·2	144·4	2·25	1·8	112·7	1·8	1·6
7		†	182·3	1·85	1·01	144·4	2·25	1·76	112·5	2·15	1·92
8	10	M. W.	182·1	1·2	0·66	145·5	1·55	1·06	115·25	1·95	1·70

The percentages are calculated on the complete figures, not on the above approximations to two decimals.

* Figures obtained from previous investigation (see (8)).

† Figures obtained from new measurements (see text).

fully dried length, breadth and auricular height of each of the four series, together with the average shrinkage in millimetres of each dimension and the percentage of this shrinkage to the final dried dimension. Rows 6, 7, 8 of Table I refer to the shrinkage of green skulls. They will be interpreted later but are inserted here for convenience of comparison with the present results.

The length is the greatest length, the skull being measured with Pearson's blocks in the Frankfort plane and includes the superciliary ridges (see Fawcett's description (2)). Breadth is measured with Flower's craniometer. Auricular height is taken on the Reserve Craniophor (fig. 1), the skull being mounted on the rounded rods in the Frankfort plane. No instrumental corrections are made, repeated check observations having shown that none are called for with the instruments used upon the present series of skulls.

Row 5 gives the result of the entire group of twenty-four skulls. There is obviously no absolutely constant relation between shrinkage and the dimension in which that shrinkage takes place. It is worth noting that the percentage of shrinkage in length is less than the percentage of shrinkage in either of the two other dimensions. This immediately suggests a possibility of some relationship of shrinkage to patent sutures like the squamous. We shall consider this possibility later. At the moment we observe that this unexpected result confirms in principle that obtained by Welcker and indicated by my earlier investigations, a result which I formerly considered to be probably invalid.

Rows 1 to 4 confirm the apparently erratic nature of the shrinkage, but also give conclusive evidence of a shrinkage in breadth and height relatively greater than in length. The average reduction taken over the three dimensions is 1·1 per cent. This is distinctly more than was obtained by Welcker but less than the amount I previously obtained when working with green skulls. Hence to this and to the other puzzling problem of differential shrinkage we must return after more of the results are set forth.

DURATION OF SHRINKAGE PERIOD

Table II presents the evidence obtained for the actual amount of shrinkage per week. Since all the skulls were not macerated at one time the total number diminishes as the number of weeks increases. There are, however, sufficient

Table II. *Average shrinkage by weeks in millimetres. Average length* 183·5 *mm.; average breadth* 140·2 *mm.; average auricular height* 113·6 *mm.*

Week (end of)	No. of skulls	Length	Breadth	Auricular height
1st	24	1·21	·65	·91
2nd	24	·15	·29	·32
3rd	24	·17	·31	·09
4th	24	·12	·12	·09
5th	22	+·07	·27	·04
6th	14	·14	·04	·12
7th	11	+·14	·04	0·0
8th	5	·10	0·0	+·10

The plus sign (+) indicates an actual average increase in the dimension instead of the customary reduction. This is probably due to changes in atmospheric humidity (see text).

data to indicate the duration of the shrinkage period. I have set out the average amounts of actual shrinkage in the several dimensions for the entire group of skulls. Each skull was first measured within twelve hours after it was taken from the macerator and at intervals of one week thereafter. The work had to be interrupted and this is the reason for the smaller number of skulls in the series after the fourth week. In each dimension the greatest reduction took place during the first week but shrinkage was by no means complete within that period; it continued with small fluctuations to about the end of the sixth week although the amount after the third week is negligible and one would be unwise in attempting to identify it with assurance upon individual skulls. Since it is not practicable to measure length and breadth to less than 0·5 mm. or height to less than 0·25 mm. it is plain that a very slight fluctuation may cause, on different occasions, a different reading to these fractions of a millimetre. This accounts for the occasional actual average increase in dimension recorded by the plus (+) sign. If shrinkage is practically negligible after the third week in ordinary room temperature it is plain that no shrinkage will take place after three weeks if the skull is subjected to a dry heat such as is experienced in this building in the Winter. Hence my previous contention that one month's drying is sufficient receives confirmation.

The detailed data of weekly shrinkage are not reproduced here for but little further information can be obtained from them than from the contents of Table II. The question of the relative humidity of the atmosphere however presents itself for consideration. No actual records of the temperature and humidity of the laboratory were taken during the period of drying but we had some weeks which were unusually hot and others in which the humidity was very great. The relation of the data to these atmospheric conditions is naturally confused since the several skulls were at quite different stages of drying but

careful study of the shrinkages suggests that drying is hastened by heat and delayed by humidity. In particular the week ending July 14 was excessively humid and among the records for that week there is an unusual feature in the number of actual increases of 0·5 mm. in the dimension. During the succeeding four weeks when no measurements were taken the skulls tended to shrink back to their dimensions of July 7, nearly all the increases proving to be temporary.

If the percentage of shrinkage be worked out for each week or for several weeks it will readily be seen that there is no constant relationship in the shrinkage. Some factors are at work which determine, for each skull, the rate of shrinkage in each dimension. Since the two halves of the skull fit throughout the shrinkage period it is further obvious that these factors, whatever they may be, act symmetrically. One should then inquire what may be the nature of these factors.

THE PROBLEM OF SHRINKAGE

Table I has already shown us that there is no real influence of sex or human Stock upon shrinkage. Small as the series in this investigation is the sex groups provide an effective brake upon any assumption of an aetiology related to Stock and likewise the Stock groups preclude any hypothesis regarding sex. That these features would have an influence upon bone shrinkage is, in any case, doubtful, for there is obviously one human type of bone and as an organic compound it is unlikely to differ with sex or Stock. The difference between Negro bone and White bone, so frequently assumed merely as a result of gross inspection, does not make itself obtrusive in the large collections of this laboratory.

Failing sex and Stock one would think of age, of cranial thickness and of patency of sutures as possibly being of some influence in this shrinkage.

We know that there are definite changes occurring in the texture and fundamental composition of bone at successive ages. The trend of these alterations in the case of the scapula has been outlined in a recent paper of great importance and suggestion by Graves (3). So far no other bone has been examined with the meticulous care necessary to discern the specific changes. But commencing in the ribs and vertebrae at about fifty years and spreading to other parts of the skeleton thereafter there is perceptible to touch and hearing a striking modification which denotes a significant change in bony composition. This will be described in detail in a later communication; it is sufficient at the moment merely to allude to it as the most fundamental of all the age changes in bone composition. Apart then from the question of suture closure we may examine the series for variations in shrinkage related to age. Table III gives a summary of these observations. In order to make any result more apparent I have set down the sum of the final measurements in length, breadth and height on the fully dried cranium, the total shrinkage of these three dimensions and the percentage of the latter upon the former. Column 6 shows that there is considerable variation in shrinkage but no real relationship to age.

Table III. *Total shrinkage in all dimensions.*

1 Skull	2 Age	3 Group	4 L. + B. + H. mm.	5 Total shrinkage	6 %	7 Cephalic index	8 Condition of cranium
897	32	Male	442·0	3·5	0·79	749	Medium
900	35	White	457·5	4·5	0·98	789	,,
883	39		448·5	3·75	0·84	762	Thick
952	40		457·5	4·5	0·98	784	Thin
939	50		438·5	3·5	0·80	884	,,
896	53		447·5	3·75	0·84	672	,,
884	60		426·5	4·5	1·05	837	Medium
895	*c.* 60		458·5	5·0	1·09	731	Thick
912	63		461·25	4·75	1·03	867	,,
903	67		433·0	4·0	0·92	775	Thin
905	77		460·5	3·75	0·81	782	Medium
724	31	Female	422·5	4·0	0·95	749	Thick
886	32	White	430·5	5·5	1·28	725	,,
893	51		395·0	4·25	1·08	773	Medium
935	60		425·25	4·75	1·12	807	Thick
874	23	Male	443·0	6·0	1·35	783	Very thick
855	28	Negro	421·5	7·75	1·83	742	Thin
906	35		436·5	5·0	1·14	727	Thick
891	38		445·75	3·75	0·84	741	,,
864	*c.* 48		448·0	6·5	1·45	767	Medium
911	58		430·5	5·75	1·34	708	,,
954	24	Female	416·0	3·5	0·84	749	Medium
773	60	Negro	434·25	5·75	1·32	773	Thin
751	65		416·0	6·0	1·44	734	Very thick

Taking the averages of all specimens in each group we obtain the following figures:

Male White.	Average	L. + B. + H.	448·2 mm.;	average	shrinkage	4·14 mm.,	i.e. 0·92	per cent.
Female White.	,,	,,	418·3 mm.;	,,	,,	4·62 mm.,	,, 1·11	,,
Male Negro.	,,	,,	437·5 mm.;	,,	,,	5·79 mm.,	,, 1·31	,,
Female Negro.	,,	,,	422·1 mm.;	,,	,,	5·08 mm.,	,, 1·20	,,

This gives a general average shrinkage of 1·13 per cent.

From these figures it appears that the average shrinkage for the cranium generally in Whites is about 1·0 per cent. of the final dimensions and for the Negro about 1·25 per cent. Whether there is any real significance in the evident Stock difference in these figures we cannot say; the groups are too small. To increase the size of the groups would be possible but the work is exacting and time-consuming. About two thousand measurements, including all check measurements, are embodied in the present investigation. Considering the individual differences it is extremely doubtful if this apparent Stock difference is real or would justify the great expenditure of time necessary for its thorough elucidation.

Thickness of the cranial bones might be invoked as a possible factor affecting the amount of shrinkage. An accurate estimate of thickness has yet to be worked out. Isserlis has asserted that there is no appreciable difference in thickness of the Negro skull as compared with that of the White (4), though this matter deserves further investigation. Meantime I have attached to Table III a general estimate of the relative thickness of the cranial bones

obtained by naked eye inspection and by palpation of the bisected cranium. A few moments' study of the records makes it clear that there is no definite relation of relative thickness either to age or to absolute or relative shrinkage.

Lest one should have some idea that perhaps shape of skull might influence shrinkage I have inserted in Table III a statement of the cephalic index of each specimen but a glance at this column serves to eliminate any such impression.

We now come to the question of suture closure and it will be remembered that Broca investigated this possibility upon a much more restricted sample and concluded that the state of the sutures is without influence (1, pp. 83, 85). It is a little difficult to set forth briefly and yet clearly the amount of closure in the several sutures. The whole question of suture closure is the subject of a memoir which, in association with D. W. Lyon, I am now preparing for publication. There is considerable individual variation in the extent of suture closure at any given age and this variation is much more marked on the external face of the cranium than on the inner surface. However, the effect of union at a suture as an agent which may conceivably influence shrinkage is not dependent upon the extent of union. If the adjacent bones are knit at a few discrete points they will be held together as firmly, from this point of view, as if the area of union were much more extensive. A detailed tabulation of the precise amount of union could therefore have no present significance and would be very confusing to the reader. In consequence I submit in Table IV merely a statement of the presence or absence of union at each suture, it being understood that if some union is indicated the amount of union is sufficient to maintain constant the relation of the apposed bones. The dimensions and actual shrinkage are expressed in millimetres, only those sutures being mentioned which conceivably might have some relation to shrinkage of the cranium as a whole. The plus (+) sign indicates some union, the cipher (0) absence of union.

On its face this table shows that the condition of the sutures can have no actual influence upon shrinkage. There is no skull in which all the sutures are patent and there are but five in which all sutures show some union, yet it is a simple matter to pick out test cases for shrinkage of any dimension. For example one might with reason expect that No. 906 would show more shrinkage both in length and breadth than No. 864 (both male Negroes) for it is not only from a younger individual but exhibits no closure in any suture except the sagittal whereas the latter has some union in all sutures. Nevertheless the shrinkage of No. 864 is 0·5 mm. greater in each direction. Coronal and Lambdoid sutures happen to present some union throughout the male White group yet the shrinkage in length varies all the way from 0·0 to 2·0 mm.

The lack of uniformity in shrinkage is well indicated by comparison of the two female Negro skulls 954 and 751. Both have the same total dimensions; the former is young and presents practically no union at the sutures, the latter is much older and shows considerable union. Yet the shrinkage in skull 751

Table IV.

			Closure of sutures							Final dimensions in mm.					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Skull	Age	Group	Sagittal	Coronal	Lambdoid	Squamous	Parieto-mastoid	Spheno-temporal	Masto-occipital	Length	Shrinkage	Breadth	Shrinkage	Height	Shrinkage
897	32	Male	+	+	+	+	+	0	+	187·5	1·0	139·5	1·5	115·0	1·0
900	35	White	+	+	+	0	0	0	+	190·0	1·5	149·5	1·5	118·0	1·5
883	39		+	+	+	+	+	+	+	189·0	0·0	142·5	2·0	117·0	1·75
952	40		+	+	+	0	0	0	0	189·5	1·5	149·0	1·0	119·0	2·0
939	50		+	+	+	0	0	0	+	170·0	2·0	151·5	1·0	117·0	0·5
896	53		+	+	+	0	+	0	+	200·5	1·5	135·0	0·5	112·0	1·75
884	60		+	+	+	0	0	+	+	172·5	1·0	143·5	2·0	110·5	1·5
895	*c.* 60		+	+	+	+	+	+	+	193·0	1·0	141·0	2·5	124·5	1·5
912	63		+	+	+	+	+	+	+	181·5	2·0	155·5	1·0	124·25	1·75
903	67		+	+	+	+	+	+	+	181·5	1·5	139·0	1·0	112·5	1·5
905	77		+	+	+	0	0	+	+	195·0	1·0	152·5	2·0	113·0	0·75
724	31	Female	+	+	0	0	0	0	+	179·5	0·5	133·5	2·0	109·5	1·5
886	32	White	0	+	0	0	0	0	+	182·0	1·0	132·0	2·0	116·5	2·5
893	51		+	+	+	0	0	0	+	162·0	2·0	125·5	1·0	107·5	1·25
935	60		+	+	+	+	+	0	+	173·0	1·5	139·5	2·5	112·75	0·75
874	23	Male	+	+	0	0	0	0	0	184·0	2·5	143·5	2·0	115·5	1·5
855	28	Negro	+	+	+	+	+	0	+	182·5	3·0	134·5	2·5	104·5	2·25
906	35		+	0	0	0	0	0	0	186·0	1·5	135·5	2·0	115·0	1·5
891	38		+	+	0	0	0	0	+	192·5	1·5	144·0	1·5	109·25	0·75
864	*c.* 48		+	+	+	+	+	+	+	189·0	2·0	144·0	2·5	115·0	2·0
911	58		+	+	+	0	0	+	+	188·5	2·5	134·5	2·0	107·5	1·25
954	24	Female	0	0	0	0	0	0	+	176·0	1·0	131·0	1·5	109·0	1·0
773	60	Negro	+	+	+	0	+	0	+	182·0	1·5	140·0	2·0	112·25	2·25
751	65		+	+	0	+	0	0	+	176·5	2·0	129·5	2·0	110·0	2·0

+ indicates some union; 0 indicates no union.

is actually almost double that in No. 954. This investigation therefore fully bears out Broca's conclusion based upon the estimation of capacity before, during and after soaking, namely that condition of the sutures is of no moment.

We have now examined the possible relation of all the factors usually called in as conceivable factors acting directly or indirectly on skeletal changes and are compelled to admit that not one of them can justly be invoked in the case of shrinkage. We are in fact reduced to the hypothesis of Broca at the conclusion of his investigation. "Les propriétés hygrométriques des crânes sont très-variables, ce qui peut dépendre à la fois de la porosité de leur tissu et de l'état de leur matière organique." In other words we come back to the composition of bone itself, the study of which has not yet advanced far enough for us either to confirm or refute Broca's suggestion.

THE CHARACTERISTICS OF SHRINKAGE OF THE CRANIUM

Baffled as we are for the present in our effort to determine the really influential factors which define the precise percentage of shrinkage there are certain features of this shrinkage which deserve some passing emphasis.

In the first place the shrinkage in the several dimensions is roughly compensatory. If, as in No. 883 there is negligible shrinkage in one dimension there will be a maximal shrinkage in the other dimensions. Excessive shrinkage in one direction, as in No. 895 is balanced by merely moderate shrinkage in the other dimensions. No doubt this generalisation must not be strained too far for the Negro males 855 and 864 do not appear to share this characteristic. It is to be observed, however, that the Negro groups show a relatively greater shrinkage than do the Whites, probably an individual variation it is true, but nevertheless somewhat disconcerting. In these Negro samples the explanation may be that the figures for shrinkage in any dimension are not really excessive.

Secondly the shrinkage is symmetrical with a result that at all stages of the process the two halves of the bisected skull fit accurately and no warping occurs.

Thirdly there is a slight play of the portions of the skull upon one another in the process of shrinkage. This is most readily studied in the breadth measurement. It results in a shifting of the site of greatest breadth during drying, the distance of the shift being out of all proportion to the difference in breadth which at its maximum amounts merely to a fraction of a millimetre. This shift with the relative stage at which it took place during drying is exhibited in Table V. Once again we have a feature of drying which presents no relation whatever to the state of the sutures reasonably presumed to possess some influence.

The first site mentioned is that of greatest breadth on the first measuring after emergence from the macerator. The number of weeks denotes the date of measurement after emergence from the macerator when the particular site became the Euryon. The last site mentioned is the permanent site of greatest breadth. Between the middle of July and the middle of August no measure-

Table V. ***Site of greatest breadth during drying.***

Skull	Group	Condition of sutures: Squamous	Condition of sutures: Parieto-mastoid	Site of greatest breadth with dates of change (weeks of drying)
897	Male	+	+	*ss.*; no change
900	White	0	0	*tp.*; *ss.* 1 week; *tp.* 3 weeks
883		+	+	*pi.*; no change
952		0	0	*pi.*; „
939		0	0	*ss.*; „
896		0	+	*pi.*; *ss.* 1 week
884		0	0	*ss.*; *pi.* 2 weeks; *ss.* 3 weeks; *pi.* 7 weeks
895		+	+	*ss.*; no change
912		+	+	*ss.*; „
903		+	+	*ss.*; *pi.* 3 weeks
905		0	0	*ss.*; no change
724	Female	0	0	*ts.*; „
886	White	0	0	*pi.*; „
893		0	0	*pt.*; „
935		+	+	*ss.*; *tp.* 1 week
874	Male	0	0	*pm.*; *pi.* 7 weeks
855	Negro	+	+	*pi.*; no change
906		0	0	*ss.*; *ts.* 5 weeks
891		0	0	*ss.*; *ts.* 3 weeks; *ss.* 6 weeks; *ts.* 7–11 weeks
864		+	+	*ss.*; *pi.* 2 weeks; *ss.* 3 weeks; *pt.* 9–13 weeks
911		0	0	*ss.*; no change
954	Female	0	0	*pt.*; „
773	Negro	0	+	*ptss.*; *pt.* 1 week; *ptpm.* 3 weeks; *pt.* 4 weeks; *ptpm.* 5 weeks
751		+	0	*pi.*; no change

As in Table IV the plus (+) sign indicates some union of the suture, 0 denotes absence of union. The site of the Euryon or point of greatest lateral projection of the cranium is indicated by letters in the manner suggested by Martin(6).

1. *pt.* Greatest breadth at the parietal eminences.
2. *pm.* „ „ midway between 1 and 4.
3. *pi.* „ „ at the lowest part of the parietal bone.
4. *ss.* „ „ at or immediately adjacent to the squamous suture.
5. *ts.* „ „ in the upper part of the squamous temporal.
6. *tp.* „ „ in the posterior part of the squamous temporal.

ments were taken; hence if a change took place during this period it cannot be defined more precisely than is done in the cases of Nos. 864 and 891. Occasionally, as in No. 773, there were two sites where the breadth was equal and greatest; these are indicated by a combination of the letters above tabulated. Of the sutures which might be suspected of influencing this measurement the condition of the squamous and parieto-mastoid alone are indicated. The sagittal which might have some remote effect, showed some union in all except Nos. 886 and 954.

From a glance at the table it is perfectly obvious that there is no effect whatever upon the stability of the Euryon ensuing from the condition of the sutures listed. Where the sutures are completely patent there may be no change in site of the Euryon during drying; even where union of the sutures precludes any actual movement of the articulating bones there may occur

quite marked and frequent fluctuations in site. No. 864 seems specially significant in this respect for its squamous sutures were four-fifths united and the parieto-mastoids completely closed, at least upon the inner cranial face. The individual variation in site of the Euryon is of no consequence. The astonishing thing is the change in its position which occurs in so many skulls, and that without any apparent strain in the skull or any resultant warping. This absence of warping in properly macerated skulls in contradistinction to that found in exhumed specimens was specially noted by Broca. Actual drying in a normal atmosphere continues over many weeks before the dimensions finally steady and the change in position of the Euryon may occur three months after the skull is taken from the macerator.

COMPARISON OF CRANIAL SHRINKAGE WITH THAT IN OTHER BONES

One would naturally inquire whether this shrinkage is uniform throughout the skeleton so that one might allow a certain percentage for shrinkage on any bone, whatever its shape. In the skull this amount would average 1·1 per cent. of the final dimension. Towards the solution of this problem we have as yet no direct evidence to go upon. In a forthcoming extensive monograph on the femur my colleague Dr Ingalls proposes to set forth the facts for that bone but until the study is completed we can only make certain inferences from data not directly apposite.

Pearson has devoted some attention to the question in the case of the femur and gives noteworthy conclusions (7, pp. 193, 194, 244). Many years ago Welcker soaked one male femur for three days and found it to increase 1·2 mm. in length. In 1873 Broca took three femora and soaked them for seven days. Of these three bones one had just been macerated that same year, one was from the fifteenth century and one was neolithic. The extension upon soaking measured 1·5 mm., 1·5 mm., and 1·0 mm. respectively. Pearson repeated the soaking experiment with one each of the femur, tibia, humerus and radius taken from burials between two and three hundred years old. After soaking for five days the measurements were contrasted with those of the bones when first received, due control measurements being used. To these notes were later added observations upon two Naqada femora soaked for five and six days respectively. The measurement in each case was the greatest length (excluding spine in tibia), for the femur the oblique length being used. It might be well to comment that this includes an angle and that the trochanteric length might give a more reliable criterion. The results obtained permit the following tabulation.

Femur 1 (Naqada).	Dry	408·0	mm.;	shrinkage	2·4	mm.;	i.e.	0·59	per	cent.
Femur 2 (Naqada).	,,	443·1	,,	,,	2·2	,,	,,	0·50	,,	
Femur.	,,	425·8	,,	,,	2·6	,,	,,	0·61	,,	
Tibia.	,,	374·1	,,	,,	1·7	,,	,,	0·45	,,	
Humerus.	,,	345·2	,,	,,	1·3	,,	,,	0·38	,,	
Radius.	,,	231·1	,,	,,	0·7	,,	,,	0·30	,,	

There is in these figures a considerable individual variation and, for the femur, they are about twice as great as those of Broca and Welcker. This perhaps may be due to the difficulty experienced by the latter workers in measuring so small a difference in length. The figures cannot be directly compared with mine on the skull but one should note that the greatest percentage increase is slightly more than twice the smallest. Now the individual variation in shrinkage of combined skull measurements in my series is from 0·79 per cent. to 1·83 per cent., or taking the maximum of the male Negroes alone, from 0·84 per cent. to 1·83 per cent. From these figures it is obvious that the extent of the shrinkage covers a considerable range. The great individual variations in shrinkage may conceivably be attributed to the differences in structure of the different parts of the same bone. Difficult though it may be, I do not think, however, that these variations entirely preclude an attempt at estimating a percentage allowance for shrinkage. Such an objective must indeed be attained if we are to make a real effort at the approximate estimation of shrinkage in bones like the vertebrae where actual shrinkage could scarcely be measured. However, individual differences make any assumptions regarding this matter unprofitable at the moment. There is one observation, however, which makes one hesitate to apply the use of the 1·1 per cent. shrinkage of the skull to any long bone. This is the fact that, by subtracting only 2·6 mm. for shrinkage in the case of the femur and 1·3 mm. for the humerus, Pearson was able to convert the measurements of Rollet on Dissecting Room bones approximately into those of Rahon for dry macerated bones (7, p. 195). Too much weight, however, must not be laid upon this agreement for it may be merely an accident of random sampling. Random sampling from a single series may result in a difference just as striking as is this agreement between samples of different series. For example Dr Ingalls informs me that the mean oblique length of the right femur of 100 male White skeletons in our collection is 457·8 mm., but in addition he tells me that in a second random sample from the same series consisting of 99 right femora the mean is 455·3 mm. and in yet another series which comprises both the foregoing and includes others to the total of 217 the average oblique length is 452·8 mm. At this point then the discussion must be left for the present, pending direct data upon the shrinkage of the long bones themselves.

COMPARISON OF DIMENSIONS IN THE WET MACERATED SKULL WITH THOSE OF THE SAME SKULL GREEN

The crux of this whole investigation is summed up in the question as to how far the dimensions of the wet macerated skull present those of the same skull green, that is to say, before maceration but after the soft parts including the periosteum have been cut away. It is essential to become acquainted with this relation since, with our knowledge of the shrinkage of the skull in drying, and our estimate of the thickness of the soft overlying tissues, it will enable

us readily to reconstruct the dimensions of the living head from those of the dry skull and *vice versa*.

There are only eight of the twenty-four skulls used as the basis for this work which were measured in the green condition upon the apparatus described in the earlier part of the communication. Taking the eight skulls I find the following average differences in dimensions when measured first in the green state and secondly within twelve hours after emergence from the macerator.

Length 0·25 mm. Breadth 0·37 mm. Auricular height 0·22 mm.

If the reader refers to my former communication (8) he will find that the possible instrumental errors, as worked out for the instruments used in these measurements, are:

Length 0·2 mm. Breadth 0·3 mm. Auricular height 0·2 mm.

In view of these latter figures it may seem absurd to base any significance upon the differences recorded immediately above. But, it may be asked, why have I not made this instrumental correction throughout? The reply is that the instrumental error is used in cases where one has reason to suspect that the conditions of the work do not permit it to be ignored. In the present investigation where very small differences were expected and the most painstaking efforts were made by instrumental standardisation and repeated check measurements to attain the greatest accuracy possible I do not consider that the small instrumental error need receive any consideration. But this elimination of possible instrumental errors itself demands that the average alteration in dimensions consequent upon change from the green to the wet macerated condition be not ignored. We are dealing with a very delicate series of measurements and although an error such as would be incurred by leaving out of account a total difference of 0·84 mm. change in dimension may seem small, yet it is quite enough to upset seriously the probable exactitude of our estimation of change in capacity. Consequently it is necessary to combine this difference between the green and wet macerated dimensions with the reduction already found to occur during drying and recorded in row 5 of Table I. The total average reduction in dimensions will now be:

Length 1·77 mm. Breadth 2·10 mm. Auricular height 1·72 mm.

For purposes of computation these figures can be simplified to

Length 1·8 mm. Breadth 2·1 mm. Height 1·7 mm. Total 5·6 mm.

and will be so used in the succeeding argument.

Eight skulls nevertheless is a very small number upon which to base an estimate of the difference between the wet macerated skull and the green skull. The macerated skulls were first measured some hours after removal from the macerator and a small amount of shrinkage might be suspected of having already taken place. Pearson indeed feared that such occurred in Broca's series, but Warren did not measure the two Naqada femora until eight or nine hours after extraction from the water bath and Pearson notes that the maximum rate of

contraction in a normal atmosphere is not reached before the second or third day. In order to check my estimate I have reproduced as row 6 in Table I the results of my preliminary examination (see (8), Table X), the skulls in which were first measured in the green state and again later after several weeks of drying. I have also remeasured these same ten skulls of row 6 after three months more and presented the results as row 7. Lastly I have taken another ten male White skulls likewise first measured in the green state and then wet after being macerated and have inserted the results of that group as row 8. Rows 6, 7, 8 all refer to skulls measured with the old apparatus (see (8)) from which the instrumental errors have necessarily been deducted. Having regard to the individual variation in shrinkage which has been shown to exist and considering the data given in the several columns of Table I, I am convinced that there is a real though small difference between the dimensions of the green skull and those of the same skull when macerated and still wet, but that this difference may be accounted for by a small shrinkage occurring in the first few hours of drying.

The conclusion just set forth must not be taken to mean that there is necessarily no transformation taking place in the bone substance during maceration. It merely denotes that actual change in dimensions occurring as a result of the loss of organic material in maceration must be very small. The further question which presents itself is why my results always show a greater difference between the wet and the dry bone, sometimes a much greater difference, than those of previous investigators. The answer is that a bone, when immersed in water after being dried, never really reaches the dimensions which it had in the green or living condition. I do not think that it is correct to argue from the dry bone to the wet one in order to obtain a true approximation to living dimensions. The only method which can inspire entire confidence is one involving the reverse process and for this reason I believe the results now obtained are more dependable than those of earlier workers.

Having outlined this conclusion it is necessary to review the work which I have previously done upon the alteration in capacity consequent upon drying of the skull. The average reduction in capacity I have shown to amount to about 50 c.c. This has been demonstrated both by direct measurements and indirectly by calculation from change in dimensions. By the direct method the average reduction in capacity of three skulls was 60 c.c. This is unexpectedly large and in consequence of the difficulties in the technique, may indeed be too great. It seems at least very suggestive that the only one of the three which was absolutely water-tight showed a reduction of only 49·5 c.c. I had been inclined to consider this as far the most accurate result, coming as it does within the range allowed by Broca. But later work and the demonstration of considerable individual variation render these deductions unwarrantable. By computation from my preliminary observations on change in dimensions I arrived at the conclusion that an average skull of about 1500 c.c. would diminish in capacity during drying about 47 c.c. It is at this point that my

former investigation ceased for lack of sufficient observations. The reduction in dimensions in transformation from the green to the dry macerated state called for in my earlier communication was the following:

Length 2·3 mm. Breadth 2·25 mm. Auricular height 1·8 mm.

These were deduced from the measurements of ten male White skulls. From the present study we find that these figures must be somewhat reduced to permit a more comprehensive generalisation. Now the type skull used previously was No. 878, a male White. Using Lee and Pearson's mean reconstruction formula No. 9(5) with the dimensions of this skull in the green state we calculate its capacity thus:

$$\cdot 000337 \times 183 \times 149{\cdot}5 \times 120{\cdot}5 + 406{\cdot}01 \text{ i.e. } 1517 \text{ c.c.}$$

Making the necessary corrections for shrinkage we have:

$$\cdot 000337 \times 181{\cdot}2 \times 147{\cdot}4 \times 118{\cdot}8 + 406{\cdot}01 \text{ i.e. } 1475 \text{ c.c.}$$

hence the reduction in capacity is computed at 42 c.c. Again this comes within the range defined by Broca and the reduction in capacity is only 5 c.c. less than I obtained in my preliminary work. This is very satisfactory and, I believe, puts the problem of skull shrinkage into such a condition that deductions made may be relied upon. In conclusion one may profitably compare the results obtained from this rather intensive study aided by instruments of precision with results just as carefully made but with less improved instruments, making allowance for the instrumental error of the latter. Taking the average shrinkage of the three sets of observations with the "old instruments" (see (8)) set forth in rows 6, 7, 8 of Table I we find:

Length 1·78 mm. Breadth 2·02 mm. Auricular height 1·97 mm.

a combined total of 5·77 mm. which is remarkably close to the revised and final sum of 5·6 mm. which I propose to adopt as the result of the present study. The tentative total of my former work which may now be discarded was 6·35 mm., but this of course was based upon a very restricted sample.

COMPUTATION OF SHRINKAGE IN VOLUME FROM CHANGE IN LINEAR DIMENSIONS

In the foregoing section I have discussed the average shrinkage as obtained directly and by computation, but to complete this study it is necessary to ascertain with what confidence the shrinkage in capacity may be calculated upon individual skulls of which one knows the change in dimensions consequent on drying. As a guide to the dependability which one may expect in this matter I have obtained the cranial capacity in the dried state of skulls 952 and 954 which served as natural *crânes étalons* in my earlier work(8). Reference to that paper will show the estimates of capacity for these skulls, with the skull intact, when the skull is bisected but with the membranes *in situ*, and finally after removal of the membranes; each estimate being the mean of seven determinations. To obtain an estimate of the capacity by the water method after thorough drying for four months I treated the skulls with cellu-

loid varnish and plasticine as already described (8), again taking the mean of seven determinations. My results are the following:

Skull 952, male White, German, age 40 years.

Capacity of green skull bisected, membranes removed	1646·5 c.c.
Capacity of dried skull bisected	1615·6 „
Shrinkage in volume directly determined	30·9 „

Skull 954, female Negro, age 24 years.

Capacity of green skull bisected, membranes removed	1173·4 c.c.
Capacity of dried skull bisected	1145·7 „
Shrinkage in volume directly determined	27·7 „

Our records of these skulls give the following dimensions in millimetres.

Skull 952.

Green measurements:	Length	190·5;	Breadth	151·0;	Auricular height		120·5
Dried „	„	189·5	„	149·0	„	„	119·0

Skull 954.

Green measurements:	Length	177·0;	Breadth	132·0;	Auricular height		110·5
Dried „	„	176·0	„	131·0	„	„	109·5

In each case the linear dimensions were measured again after the capacity determinations had been carried out on the dried skull in order to insure that the technique had not caused the measurements to increase. I was particularly anxious to be sure of this since there is such a great individual variation in shrinkage. Having satisfied myself that all measurements and estimates were as accurate as possible I next calculated the capacity from the green and dry dimensions. It is of no significance whether one adopts a local formula or one of those computed by Lee and Pearson (5), for we are not now concerned with the relative accuracy of capacity. The calculation of shrinkage is entirely independent of the accuracy in calculation of actual capacity. As a matter of fact one would expect that Lee and Pearson's formula should give a closer approximation to the actual capacity than our own formula, since the latter was computed for giving the capacity of the green skull from the dimensions of the dry. At any rate this problem has already been fully inquired into (8). No formula involving the auricular height has yet been worked out for female Negro skulls nor have we any local formula for females. The formulae used are three:

(1) W. R. U. male White formula 5. Cap. $= 5{\cdot}119\,\text{L.} + 7{\cdot}357\,\text{B.} + 9{\cdot}539\,\text{H.} - 1709{\cdot}49$.
(2) L. and P. reconstructed male White formula 9. Cap. $= {\cdot}000337 \times \text{L.} \times \text{B.} \times \text{H.} + 406{\cdot}01$.
(3) L. and P. „ female „ „ 9. Cap. $= {\cdot}000400 \times \text{L.} \times \text{B.} \times \text{H.} + 206{\cdot}60$

Now skull 952 upon calculation by formula (1) has a green capacity of 1526·0 c.c. and a dry capacity of 1491·9 c.c. This gives a shrinkage of 34·1 c.c. By the use of formula (2) the green capacity is 1538·3 c.c. and the dry capacity is 1574·1 c.c., resulting in a shrinkage of 35·8 c.c. Since the actual measured shrinkage is 30·9 c.c. either of the two mathematical methods gives a result almost if not quite as dependable as direct determination.

Skull 954 by method (3) above, gives a green capacity of 1239·3 c.c. and

a dry capacity of 1211·8 c.c. The difference between these, namely 27·5 c.c., is the calculated shrinkage, a figure almost identical with the 27·7 c.c. obtained by direct determination.

The unexpected success of these calculations decided me to make a trial of the method upon the three skulls of Table IV in my former work (8). These skulls were measured green and dry on the old apparatus and the capacity determined in the green condition with membranes *in situ* and later in the dry macerated condition. The green capacity after removal of membranes was not taken in these skulls; consequently this figure must be approximated by the addition of 50 c.c. (the mean dura volume, see (8)). Subtraction of the dry capacity from the figure now obtained will give an approximation of the actual shrinkage. In this way the "actual" shrinkage for male White skulls 878, 865, 856 is found to be 61·0 c.c., 68·9 c.c. and 49·5 c.c. respectively. Using formula (1) the respective calculated shrinkages are 63·4 c.c., 69·7 c.c. and 71·2 c.c. For skulls 878 and 865 the results again are surprisingly close, but this closeness is an accident, for the true volume of the dura of these skulls is not known. Moreover it is certain that there is great variation in dura volume. By mere accident these figures are almost as close as those for skulls 952 and 954 in which the closeness of the direct and calculated determinations is due to accuracy of data. Nevertheless it does show how reliable the calculated figure for shrinkage may be.

Skull 856 is somewhat different and is most important. There was absolutely no leak at all from this during the determination of capacity after drying; I do not believe that the few drops escaping from the other two really modify the accuracy of the results in their case but in this one there could be no question. Now whereas the shrinkage calculated from the green and dry linear dimensions is 71·2 c.c., that obtained directly, upon the assumption that the dura volume is the average amount of 50·0 c.c., is only 49·5 c.c. Presuming, as we have a right to do, from the results just announced, that mathematical calculation gives a close approximation to the truth, the discrepancy here of 21·7 c.c. may be due to an error in determination of the actual capacity under different conditions, to an error in the original determination of the green linear dimensions or to an unusually voluminous dura. It cannot be accounted for by an error in determination of the linear dry dimensions for I have repeated these and find them correct. It certainly is not due to error in the direct measurement of dry capacity for there were no leaks and the estimate is the mean of five determinations. It might be found in the original direct measurement of green capacity which is the mean of only two determinations. But the difference between these two determinations amounts merely to 15 c.c. and our experience shows that with so small a difference the mean can be depended upon as a fair approximation to the true value. We are left then with the alternatives of erroneous linear measurements of the green dimensions on the one hand, measurements which obviously cannot be reviewed, and an unusually voluminous dura on the other. The dura volume was not determined directly

in this case but even if the whole discrepancy of 21·7 c.c. were added to the mean volume of 50·0 c.c. the result would not be a startling instance of individual variation. Nevertheless I am more inclined to believe that the green dimensions are somewhat too large. A shrinkage of 4·0 mm., 3·0 mm. and 3·0 mm. respectively in length, breadth and auricular height is too large to be accepted without comment. Moreover the skull is asymmetrical, a condition which always rendered the measurement of length and to a less extent of breadth, by the old apparatus, rather difficult. Granted then that the error has been run to earth in the last category this skull stands as an exception which emphasises the reliability in general of the mathematical calculation of shrinkage as shown in the case of the other four.

SUMMARY

1. Shrinkage of the several dimensions of the cranium consequent upon transformation from the green to the dry macerated state bears no constant relation to the particular dimension. Great individual variation occurs and the percentage shrinkage, relatively small for length, increases somewhat for breadth and auricular height. On the average of all dimensions the shrinkage amounts to about 1·1 per cent. of the final dried measurement.

2. The duration of measurable shrinkage in a normal summer atmosphere is about three weeks. Shrinkage certainly continues beyond this time but it is most clearly demonstrable by a shifting of the Euryon, fluctuation of the location of which may continue for three months. Shrinkage is naturally greatest during the first week of drying. Changes in temperature and humidity do affect the reduction temporarily and may even result in slight fleeting increases in dimension.

3. Of the factors which might be invoked as influencing shrinkage directly or indirectly we are able to eliminate sex, Stock, age, cranial thickness, cranial shape and condition of sutures.

4. Of the characteristics of shrinkage three stand out fairly plainly. Shrinkage in the several dimensions is roughly compensatory. It is symmetrical. There is an actual play of the bones (or of the parts of bones) the one upon another during shrinkage, a play which is shown by the shifting in position of the Euryon, does not result in warping, and is independent of the condition of the sutures.

5. At the moment we have no data upon other bones which may be used for comparison with cranial shrinkage but this defect will presently be remedied.

6. In passing through the stage of maceration and during the first few hours thereafter the green skull loses a total average of 0·84 mm. in length, breadth and auricular height. This loss probably occurs during the first few hours of drying.

7. The average reduction in dimensions in transformation from the green to the dry macerated condition is the following:

Length 1·8 mm. Breadth 2·1 mm. Auricular height 1·7 mm. Total 5·6 mm.

8. This shrinkage corresponds to a reduction of about 42 c.c. in a cranium of some 1500 c.c. capacity.

9. Given the linear dimensions in green and dry macerated states it is possible to calculate the shrinkage in capacity and the result will be accurate within a very few cubic centimetres, any discrepancy being due to variation in the dura volume. Further the accuracy of calculation of shrinkage is independent of the accuracy in calculation of actual capacity.

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DUODENAL DIVERTICULA

By J. C. BORLEAU GRANT

The last case of duodenal diverticulum recorded in this *Journal* was one by Jackson in the year 1908. Since then a number of articles dealing with the various aspects of the subject have been published especially in the medical and surgical periodicals. In 1910 Keith(1) was able to trace 14 specimens of this condition in the various museums of the medical schools in London, and in the following year Baldwin(2) published a *résumé* of all the cases recorded in the literature dating back to Morgagni. These numbered 67 in all. The condition was therefore regarded as a rare one.

The more systematic and everyday use of the X-ray and bismuth meal in the examination of gastro-intestinal ailments has been largely responsible for bringing the subject into prominence. For example, the independent findings of three observers(3,4,5) on over 10,000 patients examined in this manner are that from 1 per cent. to 1·2 per cent. of them had duodenal diverticula. Others working independently in the postmortem room(6,7) have discovered these diverticula in 3 per cent. of about 1500 bodies, while another(2) found that of 104 cadavera 14, that is 5·7 per cent., had duodenal diverticula. They can therefore no longer be regarded as rarities. In fact, these figures suggest that their occurrence is as frequent as is that of Meckel's diverticulum. Though both are liable at times to come within the sphere of the surgeon they belong primarily to that of the anatomist.

The following points are fairly well established:

The majority are small, ranging from 0·5 to 3·0 cm. in length. They have been described in the new born, but almost all occur in the later decades of life.

An attractive explanation as to their formation is put forward by Lewis and Thyng(8,9) who suggest that the transient intestinal pockets found by them so constantly in young embryos may develop into diverticula, that is that they are congenital; by most observers, however, they are regarded as acquired.

Such diverticula may possess all the coats of the normal gut, or, as is much more frequently the case, the muscle coat is missing or is at most represented by a few scattered muscle fibres.

The great majority are to be found attached to the concave, pancreatic aspect of the duodenum, and being obscured by the pancreas, are apt to remain undetected.

Most of them spring from the second part, commonly near or along the track of the common bile and pancreatic ducts; some, like similar protrusions

from other segments of the intestinal canal, are herniated along the path of a blood vessel, as has been excellently demonstrated (1,10), whereas others bear no such definite relation. For example, of 140 cases recorded by four observers (2,11,4,3), 23 were in the first part, 84 in the second, and 33 in the third.

Usually they are to be found singly, but in the proportion of 1 in 10, or thereabouts, two or more are met with: of 129 persons in whom three observers (3,11,2) detected diverticula 11 had two or more.

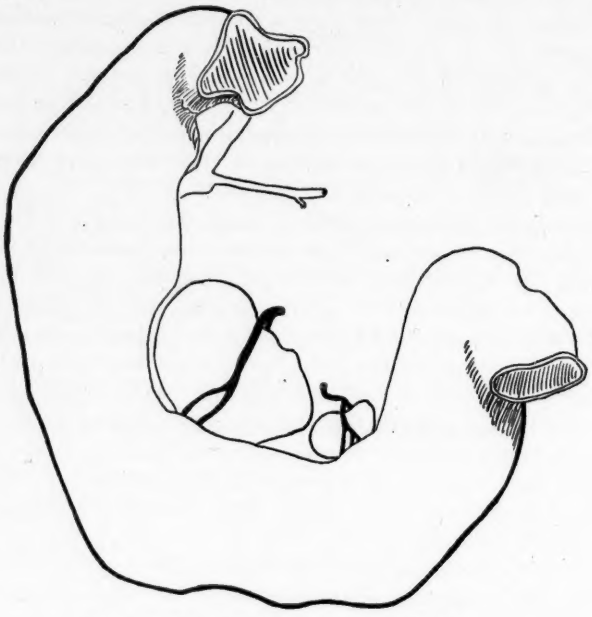

Fig. 1. Outline of Duodenum and Diverticula.

The specimen which is the subject of this note was found in the dissecting room. It has two sacs, a large and a small. The large resembles very closely in shape, size, and in position the one described by Jackson (12) in this *Journal* and depicted also in Keibel and Mall's *Embryology* (9). It is, however, slightly larger, its diameters being 4·2 × 3·3 × 1·8 cm. Being 5·0 cm. in circumference one can easily pass a finger through its mouth (it has no neck) into its large ovoid sac: the smaller, in every respect a miniature of the large, is 1·7 cm. long, and its orifice admits the stem of a pencil 2·2 cm. in circumference. The larger is 6·0 cm. and the smaller 10·0 cm. distal to the orifice of the conjoint bile and pancreatic ducts. Both sacs protrude between the same fasciculi of longitudinal muscle fibres of the gut wall as those between which the conjoint bile and pancreatic ducts pass. Further, an injected artery bifurcates at the fundus of each sac and as it were sits astride it, one branch passing on the

anterior aspect, the other on the posterior to the mouth of the sac. The impression given is that a hernia of the mucosa and of the submucous coat has taken place at the point of bifurcation of a vessel and that it has carried the bifurcation before it through the muscle wall. Sections of the sac stained with Van Gieson's stain show villi, and a hypertrophied muscularis mucosae well mixed with connective tissue fibres and, as can be seen microscopically, a muscular coat is absent.

Among other large sacs which have been described are those of Jackson (12) which measured 3·5 × 3·0 × 2·0 cm. and of Baldwin (2) 6·0 × 4·0 × 2·0 cm. Both of these like that herewith described had been treated with formalin. Case (3) estimates that a number of his cases when "barium filled" and X-rayed were 4·0 cm. long, and one which he removed by operation was 5·0 cm. in length. Downes (13) removed one measuring 4·0 × 3·5 × 3·0 cm. which like that of Case was evidently measured when fresh.

As this specimen had been laid aside with others before the abnormalities were noticed, it is not possible to state the age or sex.

I record the case as it may serve to remind those working in dissecting rooms of the condition.

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UNMYELINATED NERVE FIBRES OF THE DORSAL ROOT

By W. F. WINDLE,

Contribution No. 105 from the Anatomical Laboratory of the North-western University Medical School.

After cutting the second cervical nerve in the white rat, Ranson (1) found that nearly all of the cells in the corresponding spinal ganglion suffered chromatolysis. This occurred in spite of the fact that not more than one-third of the spinal ganglion cells are associated with afferent myelinated fibres in the nerve. Careful counts had previously shown that in this nerve there are almost exactly three cells in the ganglion for every myelinated sensory fibre in the nerve (2,3,4). The small cells, which are about twice as numerous as the large, and which had previously been assumed to be anaxonic (5), are those which show the greatest degree of chromatolysis. On the basis of this evidence, Ranson concluded that the small cells were probably associated with unmyelinated fibres in the nerve.

Both Cajal (6) and Dogiel (7) observed that the small cells of the spinal ganglia give rise to unmyelinated axones which divide dichotomously, sending one branch peripherally and one centrally. Ranson (8) confirmed these observations. He followed the fibres, after they divide, into the peripheral nerves for long distances, and into the dorsal roots for a very short distance. He was unable to trace them far into the dorsal roots because the pyradine silver method, which was used, does not give results with such small bundles of fibres as those into which the roots divide. However, he was able to see these fibres again as the dorsal roots enter the cord, where they can be followed into the tract of Lissauer (9). These unmyelinated fibres of the tract of Lissauer degenerate after sectioning the dorsal roots proximally to the spinal ganglion (10).

Miss Parsons (11), using the pyradine silver method and acid fuchsin connective tissue stain, suggested that these fibres were those of neuroglia. They did not stain with the connective tissue stain. She found them inconstantly distributed in different roots and in different parts of the same root. She also found similarities between these fibres and those brought out by using the same methods on tissues which are supposed to be composed almost exclusively of neuroglia. Miss Wilson (12) applied the differential neuroglia stains to the dorsal roots and spinal ganglia and found no neuroglia. She also pointed out that no neuroglia had ever been recorded by observers who used the Golgi method on these ganglia.

The small unmyelinated fibres of the vagus nerve, which appear as fine

black threads, when stained by the pyradine silver method (13), are identical in structure and stainability with these fine fibres of the dorsal roots. Although mechanical difficulties in staining the dorsal roots prevented Ranson from seeing the fine unmyelinated fibres except as they enter the roots from the ganglia and as they enter the cord from the roots, he felt justified in assuming their presence in the intervening portion. However, their presence here has recently been called into question (14), and so it seemed advisable to make a special effort to demonstrate them in this intervening portion of the dorsal root.

METHOD

Material was taken from the seventh lumbar nerves of large adult dogs. The whole dorsal root was divided into three equal segments. In one case the middle segment, and in another case the central segment was fixed in osmic acid. The remaining portions were prepared for the pyradine silver technique.

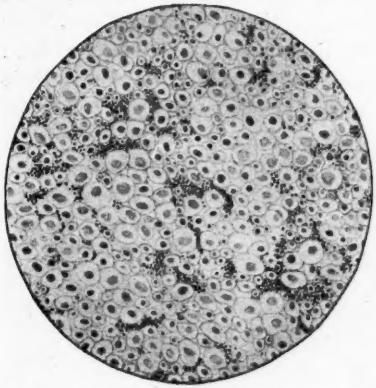

Fig. 1. Pyradine silver preparation of the seventh lumbar dorsal root of a dog about 15 mm. from the cord. Drawing from tracing made with the Edinger projection apparatus. Magnification 310.

Fig. 2. Osmic acid preparation of the seventh lumbar dorsal root of a dog about 15 mm. from the cord. Tracing made with the Edinger projection apparatus. Magnification 310.

The pieces of nerve root were threaded into strips of spinal cord (15) and tied out straight upon a glass slide, although not stretched. Imbedding the pieces in spinal cord gave sufficient bulk for satisfactory silver impregnation to take place. The tissue was fixed in ammoniated alcohol and subsequently run through the process as described by Ranson in 1911 (16). Excellent results were thus obtained.

RESULTS

The measurements of the myelinated fibres as given by Langley (14) are confirmed in the osmic acid preparations. The smallest fibres varied between two and three micra in diameter. Rarely a pale dot is seen and this might be interpreted as representing an unmyelinated fibre.

There is considerable shrinkage in the material prepared by the pyradine silver method as may be seen by comparing the two accompanying figures. The greatest amount of shrinkage occurs in the connective tissue among the fibres. A space is usually found between the very pale myelin sheath and the brownish yellow axon. This is due, no doubt, to a shrinkage in both axon and sheath. It is constant, however, and cannot be eliminated when this technique is used. The complete diameters of the myelinated fibres do not differ greatly from those of the myelinated fibres treated with osmic acid. They may be divided into the same three classes according to their diameters (14).

The unmyelinated fibres are usually seen in bundles, sometimes singly, running through the connective tissue among the myelinated fibres. They appear as small black dots when cut transversely, but the best conception of them is obtained from sections cut obliquely. Here they appear as fine threads running through the thickness of the section as the microscope is focussed up and down. Longitudinal sections show them as bundles of parallel black threads pursuing a somewhat wavy course among the myelinated fibres. They can be traced for long distances through the dorsal root and have never been seen to branch. Both drawings were taken from sections of dorsal roots approximately 15 mm. from the spinal cord, and an even greater distance from the spinal ganglia. As can readily be seen, the unmyelinated fibres are present in greater numbers than the myelinated ones. They are packed very closely together in the connective tissue but the individual fibres can be differentiated easily in thin sections by using an oil immersion lens. A few of the larger fibres are found to be somewhat over a micron in diameter, but the great majority of them measure one micron or less. Some are even less than a half micron in diameter. These diameters may be actually somewhat small since there is undoubtedly some shrinkage in the axon.

The question of the presence of these unmyelinated fibres in the dorsal roots is of considerable physiological importance because there is good evidence that they mediate painful afferent impulses (17). Since they fulfil in every way the requirements of Head's protopathic system their demonstration must be regarded as additional evidence in favour of his classification of sensory fibres. It is not improbable that the afferent myelinated and unmyelinated fibres correspond to the epicritic and protopathic fibres respectively (18).

I am indebted to Dr Ranson for calling my attention to this problem, and wish to thank him for his assistance during the work.

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A SIMPLE AND RAPID METHOD OF MICROPHOTOGRAPHY

By DAVID WATERSTON.

Anatomy Department, St Andrews University.

The writer has long felt the need of a rapid and simple method of microphotography as a substitute for drawing by hand in connection with the study and reconstruction of serial sections of embryos.

There can be no question of the value of microphotographs in such work over drawings, but the time and the expense involved in preparing a number of such photographs, each of large size, on glass plates or films, and taking prints of each have formed very serious drawbacks.

The time and the cost involved can be very greatly reduced by taking the microphotograph directly on to sensitive paper. Such photographs appear as negatives, but this involves no disadvantage, as detail is as easily recognisable in the negative as in the positive print. Only one copy of each photograph is available, but this also implies no real drawback, for it is as easy and rapid to take a second photograph as it would be to take a print from a negative.

W. His indicates a method of this kind, in which he used a Bromide silver paper.

The wide range of photographic printing papers now available suggested to me that a paper might be found which was more easily handled and more adaptable than bromide paper.

After a series of trials, gaslight printing papers were found to serve the purpose admirably, and are obtainable in almost any size required.

The writer uses for preference Illingworth "Slogas" paper, vigorous glossy, and it may be of use to give in detail the process as he now uses it.

The problem in a recent instance was to prepare a series of microphotographs at twenty diameters magnification of an embryo 26 mm. in length, cut transversely at 20 μ, and stained with haematoxylin and eosin.

It was decided to photograph every tenth section. The Edinger projection apparatus was employed arranged horizontally, and a "Summar" lens of 115 mm. focal length. The distance from lens to paper holder (a frame fixed on a wall) was approximately 9 feet. The majority of the sections were of fairly uniform size, and the magnified image could be included in a sheet of paper 12 ins. by 7½ ins.

The other sections, which were of different size, could be taken on smaller sheets. The sheets purchased were 15 ins. by 12 ins., a size very generally useful as it can be cut without waste into a large number of different shapes to suit different sections. The work was done in a large room well lighted by

yellow light. The focussing of the image on the screen, to which the paper is afterwards fixed, requires to be done with great care and it is advisable to use a magnifying lens.

A coloured screen of pale green glass was interposed between the light and the section, and with the diaphragm fully open and with no substage condenser the exposure was about four seconds. A laboratory assistant was trained to assist in developing with a metol quinol developer—development takes only a minute or two—and with one assistant it was found that twenty to thirty photographs could be completed in the hour. The detail and the contrast in the prints was all that could be desired.

Of the value of such a series of microphotographs in working out the structure of an embryo and also for teaching purposes it is difficult to speak too highly. They are immensely superior to even the most careful drawings, and they can be prepared in a fraction of the time.

I have found it advisable to have a special album made up to hold the series of photographs of each embryo.

The method is one which I can thoroughly recommend for the purposes which it is intended to serve.

A CASE OF RETRO-PERITONEAL HERNIA

By JAMES FLEMING, M.B.
Anatomy Department, Glasgow University.

The following condition was found in the abdominal cavity of a male subject dissected in the Anatomy Department of Glasgow University (October, 1922). The subject was an adult aged 70 years, and was well nourished, the cause of death being certified as cancer of the ear. On opening the abdomen, and turning up the great omentum, a large sac was observed occupying the area bounded above by the transverse colon, on the right by the ascending colon, and on the left by the descending colon. Below, the sac reached to the brim of the pelvis, and to the right side of the lower border a coil of small intestine was observed emerging from the interior of the sac. About four feet only of the small bowel lay outside the sac, and formed a loop which ended at the ileo-caecal junction. The loop was so disposed that the coil of bowel escaping from the sac emerged behind the terminal part of the ileum. In vertical and transverse diameters the sac measured 18 cms. by 17 cms. respectively. It appeared to lie more to the right side than to the left, and the hand could be passed behind the sac on the left side and so reach the middle line. Not so, however, on the right side, where the sac was limited by the peritoneum on the ascending colon, and above, where the transverse meso-colon seemed to limit its extension. Hence it was that the sac could be displaced bodily upwards and towards the right side, but not at all towards the left side. The caecum and appendix were normal, and there was a well marked ileo-caecal (bloodless) fold (pinned to the front of the sac in the sketch, fig. 6) and a very distinct ileo-caecal fossa. This fossa lay to the right and in front of the neck of the sac. The orifice of the sac lay behind the terminal part of the ileum and extended from the left or inner border of the caecum to the right side of the body of the fourth lumbar vertebra. By gently drawing on the bowel it was possible to deliver almost the whole of the small intestine from within the sac, but at the orifice the bowel was slightly adherent to the neck of the sac. Round the left margin of the neck there was very obvious torsion of the mesentery towards the cavity of the sac.

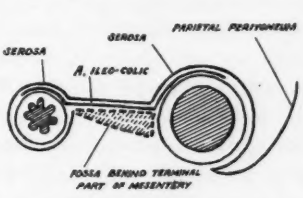
With regard to the margins of the sac, it was found that on the right side the covering of the tumour was continued laterally on to the ascending colon; above it became continuous with the under layer of the transverse meso-colon, but on the left side a marked difference was found. On displacing the sac bodily towards the right half of the abdominal cavity the attachment of the covering layer to the front of the vertebral bodies could be demonstrated, the layer there turning to the left as the posterior parietal peritoneum in that situation. Closer examination showed that while this description held good for the reflection on to the posterior wall at the base of the transverse meso-

colon and at the level of the fourth lumbar vertebra, between these two points the finger could be passed for about an inch towards the right side between the sac and the peritoneum covering the front of the aorta. This, however, proved to be a pocket, from which the peritoneal covering of the sac passed again to the left as above and below. The mesentery could be felt in front of the finger at this point; consequently the pocket actually lay behind the root of the mesentery. Immediately in front of this part of the sac there was a prominent ridge-like fold running round the attached margin and appearing in front to cross the neck of the sac. When the sac was replaced in its proper position, the ridge only appeared at the neck of the sac (fig. 6) and was continued in the terminal portion of the mesentery to the caecum, in the attenuated ileo-colic fold. Here it became directly continuous with a similar ridge descending along the right limit of the sac. This second ridge turned to the left above, along the base of the transverse meso-colon. These ridges proved subsequently to be due to underlying blood vessels and appeared, by circumscribing it, to have determined the expansion of the sac.

Briefly, then, the sac appeared to be burrowing under the transverse meso-colon above, towards the ascending colon on the right, but to be limited on the left side by the tension in the peritoneal covering due to a large underlying blood vessel. In the interval between the caecum and the right side of the fourth lumbar vertebra, the loops of bowel escaped from the sac, behind the termination of ileum, and hung into the pelvis.

When the sac was opened the floor was found to be covered by peritoneum. This peritoneal layer was reflected off, near the left margin of the sac, to form a mesentery for that part of the bowel which could not be withdrawn from the sac. On the left side the extent of the floor of the sac corresponded with the limits of the sac as seen from without, but on the right side the peritoneal layer was seen to line a deep hollow to the outer side of the first part of the duodenum, and thence to be reflected on to the roof of the sac. It follows therefore that the wall of the sac as originally opened consisted of two layers, an outer layer as described above, and an inner lining layer continuous at the margins of the tumour with the peritoneum on the floor of the sac. Underneath the outer covering first described there was obviously a complete sac continuous in all directions, except at the neck. Here its floor passed to the general peritoneal covering of the iliac fossa, while its roof formed the posterior layer of the terminal part of the mesentery. The two layers forming the roof of the sac were therefore continuous round the terminal part of the ileum, and could be regarded as the modified mesentery of this segment of the small intestine.

FIG. 1.



The mesentery of that part of the bowel within the sac (i.e. that part which could not be withdrawn) was somewhat puckered, and not so well formed as is normally the case. Also it lay so very near the left (fixed) margin of the sac

that only a narrow sulcus here separated the bowel from the lateral wall. Between the two layers of the lateral wall at this point there lay the large vessel which caused the ridge referred to above.

The floor of the sac was next separated from the posterior abdominal wall and it was found that the duodenum was a straight tube, descending vertically with a slight inclination to the left from the pylorus, to be continuous with the small intestine, without any indication of a flexure. The duodenum lay completely behind the floor of the sac above, but as it descended it pushed its way into the sac so that about two inches from the lower border of the pancreas it appeared to have a mesentery. Lower down the mesentery appeared nearly normal. The pancreas was exposed by pulling down the inner (complete) sac, whose upper limit reached the root of the transverse meso-colon. This uncovered the origin of the superior mesenteric vessels, and here the artery gave off branches to be described later, and entered between the two layers of the so-called mesentery. The inner layer was thus proved to be a complete sac, the outer layer merely an anterior covering to it. The outer layer had obviously been the original peritoneum of the right half of the posterior abdominal wall, the inner layer an expansion of peritoneum pushed before the herniating bowel.

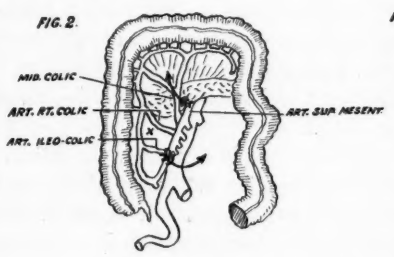
Blood vessels. On the left posterior abdominal wall the inferior mesenteric vein and the left colic branch of the corresponding artery (the vascular arch of Treitz) were in their normal position, and had absolutely no relationship to the sac. Naturally there were no duodenal fossae, as the duodeno-jejunal flexure had been pulled out into a straight tube. The superior mesenteric artery appeared at the lower border of the pancreas and immediately gave off from its anterior aspect a large trunk which proceeded under the transverse meso-colon, and then divided into branches for the colon (mid-colic) and a large branch which proceeded laterally along the root of the meso-colon towards the hepatic flexure. Here this branch turned downwards and reached the caecum (fig. 2*a*). This was the right colic artery, which normally passes directly to the ascending colon from the concavity of the parent trunk (fig. 2). This vessel was responsible for the ridge-like fold already described in the upper and right margins of the sac. At the ileo-caecal junction it was directly continuous with the blood vessel in the other ridge mentioned. This latter proved to be due to a large vessel which sprang from the left side of the superior mesenteric artery about half an inch below the combined origins of the right and mid-colic arteries. It was taken to be the ileo-colic artery which normally springs from the right side of the superior mesenteric and proceeds to the ileo-colic angle. The junction of these two vessels was tightly stretched across the neck of the sac, and here the appendicular artery was given off by the ileo-colic, this branch being an anterior relation to the right margin of the neck of the sac. These two vessels were apparently displaced by the enlarging sac, the ileo-colic to the left and below, the right colic to the right and above. From their relative positions it was therefore concluded that the sac had primarily pushed its way forward between these two vessels at a point marked

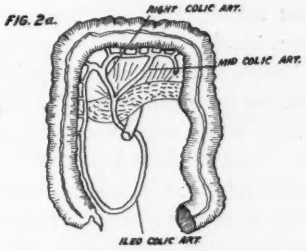
(*X*) in fig. 2, pushing the one downwards as it expanded, and the other upwards. Stretching of these vessels would tend eventually to limit this expansion.

Nothing else abnormal was found in the abdomen except (1) that the common and external iliac arteries took a sharp bend downwards into the true pelvis and then ascended straight to the femoral sheath, and (2) that the left renal vein joined the vena cava as two trunks separated by about two inches, the one passing in front of, and the other behind the aorta.

In considering the mechanics of this remarkable hernia, Moynihan's(1) essay on retro-peritoneal hernia has been freely consulted as an epitome of the literature up to that time (1906). Rendle Short(2) in the *British Journal of Surgery*, vol. III, brings the literature further up to date (1916). Moynihan describes various folds and fossae and gives a classification of retro-peritoneal herniae. Of these it will only be necessary to refer to three main varieties, viz. left and right duodenal hernia, and hernia occurring in the region of the caecum.

With regard to left duodenal hernia, Moynihan emphasises the facts (1) the inferior mesenteric vein must be in the neck of the sac, (2) the sac must





burrow upwards or to the left towards the descending colon. The present specimen obviously cannot come into this category. Right duodenal hernia would seem to be a much more plausible diagnosis, and one has been at some pains to exclude this. To quote Moynihan again: (1) The sac occupies, at any rate at first, the right half of the abdominal cavity, lying behind the ascending and transverse meso-colon. (2) The orifice is situated behind and to the left of the sac, on the lumbar vertebrae. (3) In the anterior margin of the sac there lies either the superior mesenteric artery or its direct continuation the ileo-colic artery.

In this case, however, the orifice of the sac was below and to the right, the superior mesenteric artery was, strictly speaking, behind the sac, and only the position of the ileo-colic artery in the neck of the sac could in any way correspond with the description of a right duodenal hernia. Such a hernia involves the fossa of Waldeyer (Moynihan, *loc. cit.*), which lies within the concavity of the arch formed by the superior mesenteric artery. Its orifice looks to the left, its fundus to the right and downwards, while behind it are the lumbar vertebrae covered by peritoneum. As a hernia in such a fossa increases, it

strips the peritoneum up till the duodenum is reached, this portion of the gut eventually forming a posterior relation to the neck of the sac. The orifice may increase downwards and to the right until the ileo-caecal junction is reached, as in Gerard-Marchant's (3) case. In the present case, however, the neck lies to the right at the ileo-caecal junction and moreover the duodenum is pulled out straight and obviously has no relation to the neck of the sac. From Moynihan's description, therefore, a right duodenal hernia may justifiably be excluded.

Turning now to the ileo-colic area, the possibility of certain fossae having to do with the hernia must be considered.

(1) The superior ileo-caecal fossa (Treves (4)) was obliterated by the stretching of the ileo-colic fold with the included ileo-colic artery tightly across the neck of the sac.

(2) The inferior ileo-caecal fossa was distinctly in front of the neck as seen in the sketch (the bloodless fold is pinned to the front of the sac).

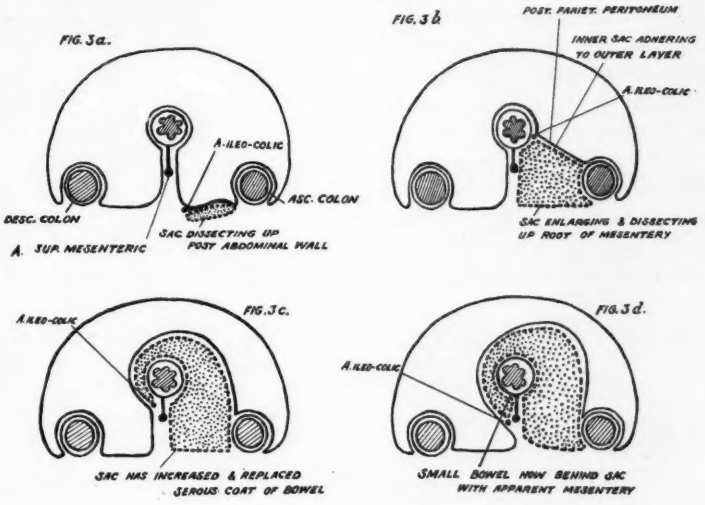
(3) There were no fossae behind the caecum or the ascending colon, consequently retro-caecal and retro-colic herniae can be excluded.

At this stage it may be well to attempt to elucidate the meaning of the curious arrangement of peritoneal layers found in connection with this tumour, turning later to the merely speculative discussion as to its origin. If it be granted that the bowel entered some fossa, normal or abnormal, lying behind the terminal part of the mesentery, and immediately to the left of the caecum, a ready explanation can be found.

Fig. 1 shows the last part of the mesentery and the caecum in section. The ileo-colic artery anastomoses with the termination of the superior mesenteric between the two layers of this part of the mesentery. Given a fossa here, it would have two layers in its roof with the artery between them, and as its floor the peritoneal lining of the iliac fossa. Bowel entering the fossa would lie behind the terminal part of the ileum and if it increased it would always have the same relations to its floor and roof as it had at the neck. That is, it would have the anterior and posterior layers of the mesentery in front of it, and the lining of the iliac fossa behind it. But the anterior layer of the mesentery, traced up, is continuous with the under layer of the transverse mesocolon; traced laterally to the right it covers the ascending colon, while to the left it covers the small bowel and then the posterior abdominal wall on the left of the root of the mesentery. This corresponds to the outer layer of the sac as described, and if the forward bulging of the sac occurred primarily at the position (*X*) in fig. 2, the limits would be determined by the constricting action of the stretched right colic and ileo-colic arteries, and the latter artery swinging to the left with the growing sac, would appear to arise from the left side of the parent trunk. The case of the right colic artery is not quite so clear, arising as it does in common with the mid-colic, but that it has been displaced upwards cannot be doubted.

The herniating loops may thus be imagined to have pushed in front of them a sac which dissected up the posterior parietal peritoneum, and as it did so,

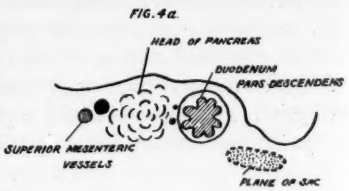
replaced that layer with its own floor, while its roof adhered to the layer it was stripping up. This means that from the level of the ileo-caecal junction below to the transverse meso-colon above, and laterally to the ascending colon, the peritoneum was, as it were, blown off the abdominal wall from behind, but as this was taking place the sac proper invested the structures, thus denuded, with its own peritoneum. As the process extended medially the ascending loop of the duodenum was stripped along with the attached suspensory ligament of Treitz. This brought about a ptosis of the duodeno-jejunal flexure. Meanwhile the peritoneum was stripped up from the root of the mesentery, off the bowel itself, and so on until the left side of the root of the mesentery was reached. Then the bowel continuous with the descending part of the duodenum was stripped and pulled out straight, the floor of the sac was spread over it, and by thrusting itself forward the denuded gut contrived to acquire a new

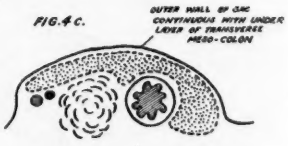


mesentery from the floor of the sac. A reference to figs. 3 and 4 (sections viewed from above) will explain in detail how this metamorphosis may have been brought about, and how the superior mesenteric artery has maintained its original relationship to the bowel.

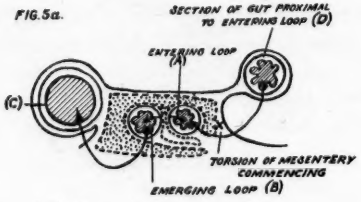
Further, the spread of the inner sac to the left lateral side of the root of the mesentery would tend to be limited by the stretching of the ileo-colic artery which, originally lying beneath the peritoneum of the right posterior abdominal wall, has now been swung to the left, and lies between the outer and inner layers of the sac at its left attached margin. All this has been brought about by the sucking into the cavity of the sac of more and more loops of small intestine. The primary entering loop presumably lay below the ileo-caecal junction originally. Such an entering loop would draw in bowel both proximal and distal to it, but from the general direction of the peristaltic

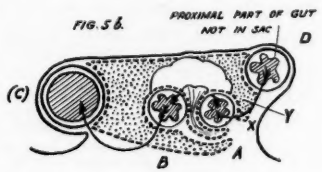
waves it would be more likely to use up the bowel which lay proximal. Assuming then that it did so, a time must have come when the proximal part of the bowel was pulled taut. Then either strangulation of a loop must have occurred, or straightening of the duodeno-jejunal junction. The latter happened, a process which would be greatly assisted by the simultaneous stripping up of the original peritoneum of this part of the gut. The loops of bowel proximal to the entering loop thus became straightened out, and were pulled in behind the sac by the extension of the latter to the left side of the root of the mesentery.

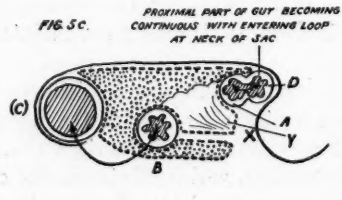


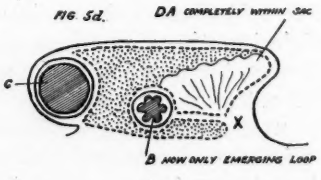


In Fig. 5 sections of the lower end of the sac and the adjacent viscera, viewed from below, are figured. They show the supposed sequence of events leading to the apparent inclusion of the distal part of the proximal (duodeno-jejunal) loop in the sac. The diagrams represent progressive stages of a process, and not different levels of the final stage. In all the figures *D* represents the cut distal part of the straightened duodeno-jejunal loop. Obviously then this section (*D*) is more or less fixed as is also the section of the caecum (*C*). *A* and





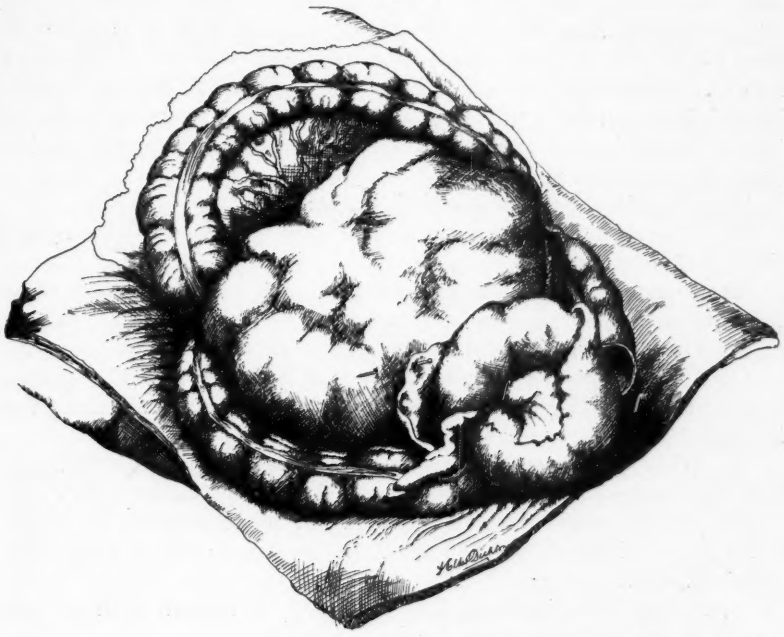




B represent sections through the entering and emerging loops respectively of the herniating small bowel. It will be equally obvious that the particular part of the bowel thus represented will not be constant. In other words the section is meant to indicate the parts of the small bowel which at different

stages lie in the neck of the sac. Naturally as the hernia enlarges an ever increasing length of bowel will separate *A* from *B*. The cavity of the sac is stippled, and represents a section immediately above its neck. The arrows indicate the proximal and distal connections of the two limbs of the herniating gut, the region marked (*X*) the position of the supposed torsion and stretching of the mesentery. For the sake of simplicity the mesenteric attachments of the herniating loops are represented as double, i.e. a double peritoneal layer is figured as passing to each sectioned lumen.

FIG. 6.



This general statement describes the state of affairs in fig. 5 *a*. In fig. 5 *b* it will be noticed that the arrow indicating the coil of bowel joining *D* to *A*, is being pulled more into the sac, and this loop is gradually being undone. More bowel is now in the sac, and the continuity of the entering and emerging loops is indicated by lines joining them. The continuity of their mesenteries is also suggested by the thin black lines. It will be clear from this diagram that the lining of the sac at the point (*Y*) has only to be thrown over the wall of the gut intervening between *D* and *A*, in order to get the appearance shown in the next figure. This of course can only have been brought about by the stripping of the serous coat of *A* by the expanding lining of the sac. In fig. 5 *c*, *A* and *D* are almost continuous, and the peritoneum at (*Y*) has become the mesentery joining *DA* with *B*. In the next figure (5 *d*) the process is completed and the mesentery of *A* is one with the mesentery of *D*, the loop thus formed

projecting upwards into the cavity of the sac, immediately above its neck. In the last section, actually through the neck of the sac, only the emerging loop appears.

A large hernia developing in such a way must of necessity have grown very slowly and presumably have started in very early life. As the caecum and appendix were normal in position and there was no ascending meso-colon, evidently the rotation of the gut had occurred in its usual way and the downward growth of the caecum had been completed. A fossa of Hartmann is described (recessus post-iliaci of Tarentzky (5)) as lying behind the meso-appendix. "In some cases the lower attachment of the mesentery to the iliac fossa is prolonged into a sharp fold...it springs from the ileo-colic angle and from the posterior and inner aspect of the caecum, and runs backwards to the iliac fossa." (Moynihan, *loc cit.*). It is generally accepted that a case described by Snow (6) occurred into this fossa. A fossa in this position might conceivably determine the formation of the hernia, with the termination of ileum, the meso-appendix and its artery, lying in front of its orifice.

To summarise the points about this hernia:

(1) A sac growing chiefly at the expense of the peritoneum to the right of the root of the mesentery.

(2) An anterior covering to the sac formed by the pushing forward of the right half of the posterior parietal peritoneum.

(3) The sac overlapping the straightened duodenum.

(4) This straight tube lying behind the sac but by its forward projection into the sac, appearing to have a mesentery. (This tube was about one foot in length.)

(5) This apparent mesentery becoming continuous, at the neck of the sac, with the true mesentery of the most proximal loop of herniating bowel.

(6) The true mesentery greatly twisted and elongated at the left margin of the neck of the sac in order to permit the greater part of the small bowel entering the sac.

(7) A single emerging loop, slightly adherent to the neck of the sac, and distant about four feet from the ileo-caecal junction.

(8) Termination of ileum in front of the neck of the sac.

(9) Neck of the sac bounded in front by (8), to the right by the caecum, to the left by the root of the mesentery, and behind by the peritoneum of the iliac fossa.

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A LARGE DIVERTICULUM OF THE URINARY BLADDER

By CECIL P. G. WAKELEY, F.R.C.S. (Eng.).
Assistant Surgeon and Teacher of Clinical Surgery, King's College Hospital.

Congenital diverticula of the bladder may be classed into two principal groups:

(1) Those arising in relation to the allantoic tube, and consisting of an urachal cyst opening near the summit of the bladder, and connected by the urachus with the umbilicus.

(2) Those involving the lower end of the ureter, or opening into the bladder in the vicinity of an ureteral orifice; to which category the present specimen belongs.

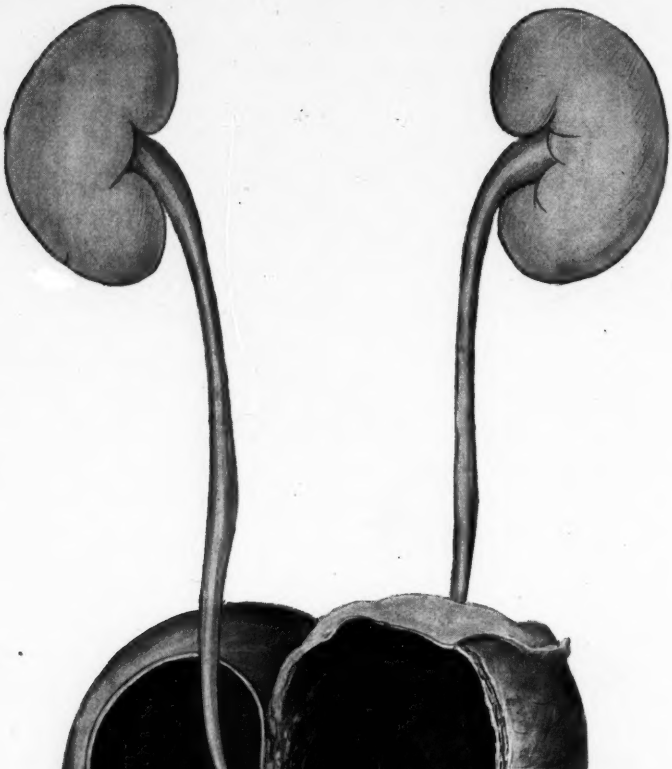
Urachal or allantoic cysts are well known and have been described by Lawson Tait (*Brit. Gyn. Journ.* vol. II. p. 328), and other authors. They are lined by a stratified layer of epithelium corresponding to that of the normal bladder and the walls consist of fibrous connective tissue containing unstriped muscle.

The second group of cysts or diverticula connected with the bladder have been described under the titles, supernumerary bladders, multiple bladders, duplication of the bladder, etc. Some of these cases probably represent an exaggeration of the acquired condition of sacculation and are generally accompanied by stricture of the urethra or some obstruction to the outflow of urine. Other cases are unaccompanied by any sign of obstruction and may consist of two symmetrically placed sacs, right and left, opening into an otherwise normal bladder near the ureteral orifices and have all the appearances of a congenital abnormality.

A case was described by Erichsen (*Science and Art of Surgery*, p. 1129) in which two enormous sacs opened into the bladder, one on each side about 1½ inches above the opening of each ureter and equidistant from the median plane. The openings of the diverticula were rounded and sufficiently large to admit the tip of the little finger. The walls were thin and composed chiefly of mucous membrane and peritoneum, possibly a few scattered muscle fibres; the ureters were adherent to the cyst wall and compressed. The pelves of the ureters were dilated and the pyramidal portion of the kidneys absorbed.

In one case reported in Treves' *System of Surgery* a woman was found to have five bladders, five kidneys and six ureters. Such cases indicate the possibility of these abnormalities being due to the formation of accessory renal diverticula which may or may not become connected with the metanephros.

In some specimens the bladder is divided by a median septum. A possible explanation of this condition is the enlargement and persistence of the "cloacal



horns" of the ventral part of the cloaca which forms such a prominent feature of the developing bladder at the 11 mm. stage before the lower end of the mesonephric duct has become included in the cavity of the bladder to form the trigonum vesicae.

The patient from which this specimen was removed was a male *aet.* 50 years

who died from uraemia three days after admission to hospital. Just prior to admission the patient consulted his doctor because he felt ill and drowsy and was suffering from diarrhoea. He was a big man and on examination he was found to have some diminished resonance at the left base and some very fine crepitations; he was coughing but could not bring up anything, the heart was normal, the pulse was about 100, and the respirations were 28. There was no tenderness in the abdomen. The urine on examination was found to contain blood casts and *B. coli* in large numbers. There seemed sufficient in the left base to make this a case of pneumonia and to dispel the supposition of surgical kidney. There had been no pain in the loins and there was no tenderness over the kidneys, and the blood pressure was not high. The patient was kept in bed and the signs in the lung cleared up after a few days. However, a few days later the patient developed coma and was admitted to hospital; he died after two days without regaining consciousness. He was catheterised and no stricture was present. There was no history of syphilis or gonorrhoea. Post-mortem examination revealed a very large diverticulum of the bladder, it seemed about the size of half a distended bladder and its capacity was about 10 ounces. It was situated on the right side of the bladder and communicated with that viscus by a round hole which would just admit a pencil. The edges of the orifice were sharply defined. The bladder wall was a little thickened owing to the chronic cystitis which was present. There were no signs of any other diverticula or pouches in the bladder, nor was there any sacculation or trabeculation. The orifice of the diverticulum was situated just above the right ureteral opening. Both ureters were thickened. The kidneys were not enlarged and on microscopical examination the vessels of the kidney substance, especially those accompanying the renal tubules, were found to be engorged. Except for some pneumonic patches in the left lung the rest of the body appeared normal. A section of the wall of the diverticulum revealed the presence of muscle fibres; this fact some investigators including Virchow and Englisch consider of importance because they state that when muscle is present in the diverticulum it is congenital and when absent it is acquired. In the Johns Hopkins' *Hospital Reports* for 1906 Young always found muscle in the walls of the diverticula he examined although in some cases the layer was very thin.

It is a question if diverticula of the bladder are ever acquired. Sir John Thomson Walker in his well known text-book on *Surgical Diseases and Injuries of the Genito-urinary Organs* states: "While many of the diverticula are congenital, some are apparently due to urethral obstruction, and are met with in cases of stricture and enlarged prostate. In some cases I have found a history of pelvic cellulitis (from appendicitis salpingitis, etc.) and traction from without by adhesions may have been a factor."

Hyman (*Surg. Gynec. and Obst.* Jan. 1923) reports three interesting cases of diverticula of the bladder in children, and he is of the opinion that undoubtedly there will be an increase in the number of cases reported as soon as cystoscopy in children becomes more of a routine procedure.

ANOMALOUS CARPAL BONES

By E. JOYCE PARTRIDGE, F.R.C.S.
The London School of Medicine for Women.

The accompanying sketches are illustrations figs. 1 and 2 of a right carpus and fig. 3 of the left unciform found in the same dissecting room subject. It will be seen that the trapezoid in the articulated carpus is apparently divided into two halves as is also the disarticulated unciform from the opposite hand.

Fracture as a cause of the condition can be eliminated as the trapezoid exhibited a perfectly symmetrical arrangement in the two hands, and in these circumstances the unciform may also be regarded as sharing in the same anomalous development.

These divisions of bone, granted that they are not fractures, are to my mind worth recording because of their probable embryological significance.

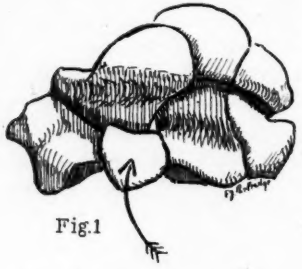


Fig.1

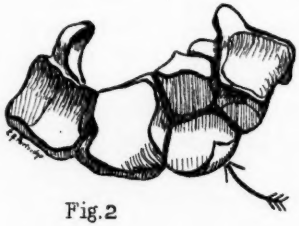


Fig.2

Fig.3

That the unciform represents the fusion of two elements (carpalia of the primitive type of fore limb) of the distal row is a generally accepted view. Although the hamulus is known to chondrify independently I cannot find a description of the extension of this independent chondrification into the body of the bone as is shown in the illustration (fig. 3). Do the two ossicles represent elements which are independent in the primitive carpus, and if such be the case why are they disposed in an antero-posterior plane and not placed side by side, are questions of some considerable interest.

With regard to the trapezoid as shown in figs. 1 and 2, the question arises as to whether its division is simply a peculiarity of development of this bone, or whether either part of this bone represents an element usually lacking from the human hand, but found in more primitive types.

Lebouceq expressed the view that in the human carpus the centre of chondrification corresponding with the os centrale fuses in all probability with the scaphoid, and enters into the formation of its posterior border just below the

oblique ligamentous ridge. When an os centrale appears as a separate bone, it is said to be found always on the posterior surface of the carpus in the angular interval between the scaphoid, the os magnum and the trapezoid. Admitting it to be possible for the os centrale to appear in these two different ways, is it not conceivable or even easy to imagine that it may undergo a still further distal displacement, appear on the back of the trapezoid, and assume the form shown in the illustration of the carpus?

In this connection it is interesting to note, that the carpal bone most commonly found divided by Pfitzner was the trapezoid; indeed he described a new supernumerary carpal bone in the form of the "Trapezoide Secundarium." Perhaps his description of this division of bone was only an indication of the frequency with which the os centrale appears at the back of the trapezoid.

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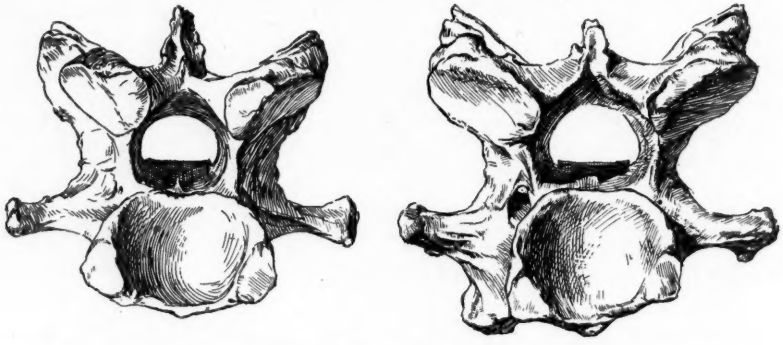
ABNORMAL CERVICAL VERTEBRA OF HORSE

By B. GORTON, M.R.C.V.S.

During the examination of the carcase of a horse which was destroyed recently, it was noticed that the seventh cervical vertebra was abnormal.

Normally the lateral process of this bone is a single outwardly projecting process which does not present at its root a foramen transversarium found in a typical cervical vertebra. The inferior or ventral spine, on the ventral aspect of the centrum, is an elongated bifid ridge quite small in size. The dorsal spine (spinous process), on the other hand, is conspicuous and is a definitely outstanding prominence.

In the abnormal vertebra under consideration the lateral process on the right side is normal, being single and untraversed by a foramen; on the left



side, however, the process is double, having two well marked prominences, a dorsal projecting outwards and a ventral projecting downwards. The dorsal part, which has a blunt extremity, is apparently the counterpart of the whole process on the right side. It is significant that the ventral prominence is in line with the capitular facet for the first rib which, in the horse articulates with the seventh cervical vertebra as well as with the first thoracic. The root of the process is pierced by a large foramen.

The inferior spine, on the ventral aspect of the centrum, is represented by a rounded ridge not quite median in position.

Another departure from the normal is seen in the fact that the right capitular facet for the first rib is slightly more dorsal in position than that on the left.

The asymmetrical condition scarcely calls for comment, as anomaly involving a vertebra is most frequently one sided.

The condition on the left side may be explained by regarding the dorsal prominence of the lateral process as representing the transverse process proper, and the ventral process as being costal in nature. In the normal seventh cervical vertebra the transverse and costal processes are indiscriminately fused, as is the condition on the right side. On the left side, however, the distinction between the two is accentuated not only by the presence of a costo-transverse foramen, but by the distal independence of the greater part of the costal element.

In short there is apparently an asymmetrical attempt at the exhibition of a cervical rib.

ON MAXIMUM ARM STRETCHING

By EDGAR F. CYRIAX, M.D. (Edin.).
London.

Let it be supposed that a subject assumes what is known in Swedish drill nomenclature as "yard" position, i.e. he abducts both arms until they come to lie horizontally outwards, keeping his scapulae drawn backwards and inwards the whole time[1]. From this position it is possible by active effort to perform "maximum arm stretching sideways," i.e. to stretch the arms still further horizontally outwards thereby increasing their lateral span by two inches or more. This movement is one which with various modifications as regards direction, such as being combined with different amounts of flexion and abduction and the reverse, is continually being used in many games and sports in which efforts of greatest stretch in order to reach a ball or a person, play such an important part.

The mechanism involved in this arm stretching cannot be found described in any books on physical drill or athletics, and almost all anatomy books entirely ignore it[2]. Not only this but enquiries from both medical men and physical training experts have shown me that there is a wide-spread and erroneous belief that such maximum arm stretching sideways is effected by contraction of the muscles of the arm and forearm. This mistake has probably arisen because such muscle contraction is involuntary and nearly always accompanies the stretching, but it is of course obvious that it cannot actually cause any elongation, as it is impossible that contraction of muscles passing over a joint can do otherwise than approximate its opposing articular surfaces. Further, it can easily be shown that such arm and forearm contraction does not assist at all in the stretching because it can be performed equally well (if indeed not a little better) while the arm is kept resting on a horizontal table with all its muscles relaxed.

In order to discover the mechanism involved I examined a number of subjects of all ages and both sexes; some of these were quite used to physical drill and games, others were quite the opposite. This factor, however, does not cause any material differences in what takes place during the arm stretching, the component parts of which are as follows:

1. *Scapula.* This bone moves around the chest wall en masse, rotating as it goes so that the acromion becomes elevated to a greater degree than the

[1] Compare the author in *Journ. Anat.* li. 396–399. 1916–17.

[2] The only exception that I know of is Quain (*Elements of Anatomy*, ii. pt. 2, 213, 1892) who makes the brief statement that "the serratus magnus, by withdrawing the base of the scapula from the spinal column, enables the arm when raised from the shoulder to be still further outstretched, as in the movement termed extension in fencing."

upper angle. There is a tendency to elevate the scapula as a whole, but this leaves the greatest span obtainable practically unchanged.

2. *Clavicle.* During the first part of the movement this bone follows the movements of the scapula, i.e. its acromial end moves forwards and upwards, a rotation occurring round a centre in the sterno-clavicular joint. This may be all that takes place, continuing in this way until the maximum stretching has been performed, but in many persons, chiefly young subjects and in those used to physical drill, as the stretching proceeds, the interval between the sternal end of the clavicle and the sternum widens, and the whole bone moves a little outwards en masse; in addition the sternal end of the bone may move backwards, finally attaining a position as much as $\frac{1}{4}$ inch or even more behind its original site. This last mentioned movement backwards of the head of the bone diminishes in direct proportion to the amount that the arm is carried backwards during the stretching movement, and the reverse occurs when the arm is carried forwards.

Most anatomy books refer to the possibility of gliding movements taking place between the clavicle and acromion. During maximum arm stretching sideways such lateral gliding would, if it existed, be of great service in increasing the lateral span, but none can be detected either by inspection or palpation, and I am indebted to Dr R. L. Rawlinson for having screened several cases for me and with the X-rays proved that no such gliding movement took place.

The movements of the clavicle just described are as far as I can judge merely a passive accompaniment of the movements of the scapula and are not brought about by any active contraction of its integral muscles.

3. *Humerus.* It is evident that were the gleno-humeral joint kept immovable during the maximum arm stretching sideways, the whole upper extremity would be moved en masse forwards and upwards as the scapula advanced. In order to prevent this and keep the arm continually horizontal, the humerus must, as the scapula moves, be relatively abducted and moved backwards in the horizontal plane.

Concerning the muscular actions involved in the arm stretching, apart from the involuntary contraction of most of the muscles of the extremity, as already mentioned, which has no effect whatever upon the stretching *per se*, there is also a simultaneous contraction of many of the muscles of the shoulder girdle in order to keep the arm abducted and to give that necessary fixation without which no movement can proceed. This at first makes it very difficult to distinguish between such muscles of fixation and muscles actually performing the stretching. If, however, the arm be first abducted to a right angle and the elbow semi-flexed and the whole arm supported by resting it on a table, the fixators are thrown out of action and only those muscles will contract which are actually concerned in the movement.

With the arm in this position definite signs of contraction were found in two muscles only, the serratus magnus, which moved the scapula round the chest wall, and the posterior third of the deltoid, which moved the humerus

backwards. The lower fibres of the serratus magnus appeared to act more powerfully than the upper, but this point could not be determined easily owing to the thickness of the subcutaneous fat and to the condition of tension of the two axillary folds.

During the last stage of the stretching the subject frequently experiences tingling sensations in the arm as a whole, specially its anterior aspect. The sensations in the forearm are generally relieved by relaxing the forearm muscles and flexing the wrist, and the sensations in the entire arm are similarly affected by flexing the elbow joint, even if the surrounding muscles are not relaxed. It is therefore highly probable that the sensations in question are due to elongation of the nerves of the front of the arm and not to any pressure upon them in the axilla or on the blood vessels in this region.

In conclusion I may state that I examined two pathological cases, namely one of "floating clavicle[1]" and one of cleidocranial dysostosis in which one clavicle was entirely absent and the other represented by a cartilaginous rudiment about three inches in length, and found that as far as the scapula and humerus was concerned their behaviour during maximum arm stretching sideways appeared to be identical with that of normal subjects.

[1] See the author, *Anat. Rec.* XVI. 379–380. 1919.

ON "EXCENTRIC" CONTRACTION OF MUSCLES

By EDGAR F. CYRIAX, M.D. (Edin.).
London.

For the performance of voluntary movements there are two distinct kinds of muscle contraction, namely:

(*a*) Where the contraction of the muscles is able to overcome the resistance offered to them, and they thus become shortened,

(*b*) Where the resistance overcomes the contraction of the muscles, which thus become elongated.

The first person who scientifically distinguished between these two varieties of muscle contraction and who employed them from the therapeutic aspect was the Swede P. H. Ling (1776–1839), in whose system the so-called resisted or "duplicate" movements played such an important part. These exercises, according to where the resistance was applied, brought into play either the same muscles continuously or else antagonistic ones alternately. The terms used by Ling and his school to express the two kinds of contraction mentioned were either "half-active" or "active-passive" when the muscles shortened, and "half-passive" or "passive-active" when they elongated; these terms were, however, somewhat misleading as there was no passivity in any of them. About 1847 Neumann[1] introduced the terms "concentric" and "excentric" respectively which have superseded the former ones and have been retained ever since in Swedish gymnastic literature. For this reason I have adopted them in this paper.

Now although writers on anatomy, clinical medicine and neurology do full justice to concentric contraction of muscles they almost totally ignore the fact that there is such a thing as excentric contraction thereof. This is all the more surprising because physiology text-books give it a good deal of their attention. As regards the first mentioned authors, the only hint of the existence of excentric contraction is found in a few anatomy books who mention that adduction of the previously abducted humerus is performed by the adductors assisted by the weight of the arm (see A below) and that the weight of the lower jaw plays a part in depression of the same. Otherwise the possibility of gravity playing a part in any other movement is never entertained.

Neglect to take into account the existence of excentric contraction of muscles is in my opinion largely responsible for a number of statements in the above text-books which are either incomplete, or at best only partially

[1] *Wochenschr. f. d. ges. Heilk.*, 1849, pp. 229, etc., 1850, pp. 65, etc.; *Die Heilgymnastik*, 1852, pp. 15, etc.

correct, and which have in consequence led to many misconceptions. The following examples will show this:

A. *Adduction of the shoulder joint.*

One frequently meets with statements to the following effect: "Abduction is performed by the deltoid and supraspinatus, assisted by certain other muscles that rotate the scapula....Adduction is performed by the adductor (pectoralis major, teres major, subscapularis, latissimus dorsi) aided by the weight of the arm...." It is a curious fact that one never finds any mention of the fact that the scapula during such adduction goes through the reverse of what it did during abduction, some of its muscles contracting concentrically if resistance is being offered to the movement. Furthermore the latter half of the statement is correct only in the following instances:

(*a*) When resistance is opposed to the movement which the unaided weight of the arm is either totally unable to overcome or else cannot do so with sufficient rapidity.

(*b*) When the movement has to be performed with great speed as for example in the case of defensively bringing the arm sharply to one's side after receiving a sudden dig in the ribs.

In all other cases, the muscular mechanism is one of the following:

(*a*) When the subject who has abducted his arm, suddenly relaxes the abductors, thereby letting the arm drop passively to his side; then the movement is effected by the weight of the arm alone, the adductors not undergoing any concentric contraction, but merely becoming passively shortened.

(*b*) When the subject who has abducted his arm performs co-ordinated adduction in the absence of any opposing force. The movement is then brought about by excentric contraction of the abductors, thus allowing the weight of the arm to overcome them. Just as in (*a*) above, the adductors merely undergo passive shortening.

B. *Lateral flexion of the trunk on itself.*

One frequently encounters statements to the following effect: "The two halves of the erector spinae (and its prolongations) acting simultaneously maintain the erect position and extend the trunk....Flexion of the trunk to one side is produced by the contraction of the erector spinae of that side...." The latter half of this statement is correct only in the following instances:

(*a*) When the movement has to be performed with great rapidity, as is the case in many games in order to reach a ball, etc. Even under these circumstances the lateral flexors of that side to which the bending is performed relax towards the end of the movement, the corresponding muscles on the other side undergoing progressively increasing excentric contraction, this being done in order to modify the speed of the movement and to prevent overstrain and possibly sprains arising in the back.

(*b*) When the subject to commence with is in such a position that the pull of gravity is either eliminated, as when lying on his face or back, or else re-

versed as when lying on the side opposite to the one which is to be laterally flexed (and of course in all intermediate positions between the two).

(*c*) When resistance is offered to the side of the body that is to become laterally flexed, provided that it be in sufficient amount to prevent gravity performing the movement unaided, i.e. without the help of the lateral flexors of that side.

In all other cases the muscular mechanism involved may be divided into three stages which are not of course absolutely distinct, but slightly overlap. For the sake of convenience of description it will be assumed that the flexion is to take place to the left side, and the following is the sequence of events:

(*a*) The lateral flexors of the right side transform their static into excentric contraction, those on the left side changing theirs into passivity. Gravity will thus be enabled to produce the flexion to the left, the right lateral flexors becoming elongated and the left ones shortened.

(*b*) As the movement proceeds, the gradually increasing elongation and tension in the right lateral flexors offers progressively increasing resistance to the flexion, thus proportionately relieving these muscles of the necessity for excentric contraction, until finally a point is reached when the amount of the latter becomes nil.

(*c*) The left lateral flexors then commence to undergo concentric contraction and they continue to do so in continually increasing amount until they together with the pull of gravity to assist them cannot bring about any further elongation of the right lateral flexors. The physiological limit of the movement has then been reached.

The reverse stage of the movement is of course effected by concentric contraction of the right lateral flexors overcoming the pull of gravity on the left side and passively elongating the left lateral flexors.

The fact that the theory is so prevalent that lateral flexion of the side is caused by concentric contraction of the muscles of the same side is, I consider, largely responsible for the widespread erroneous view that in cases of lateral curvature the muscles on the concave side are contracting more powerfully than their antagonists. If this were true, it would be impossible to assume the erect position at all as a rapid and powerful trunk flexion to the concave side would result as soon as this was attempted. It is of course evident in such curvatures that the muscles on the convex side must in order to maintain the erect posture contract as much as those on the concave side plus the unopposed force of gravity acting down that side.

C. *Flexion forwards of the trunk on itself.*

It is generally stated that this movement is brought about by contraction of the various anterior muscles of the trunk. But, just as in the case of lateral flexion of the trunk on itself, so is this statement true only in the case of having to execute the movement very quickly, or where the pull of gravity is eliminated as when lying on the side, or reversed as when lying on one's back (and in intermediate positions), or when resistance is applied to the front of

the body. In all other cases this movement is performed by excentric contraction of the erector spinae which diminishes until it becomes nil, at which juncture the force of gravity which cannot elongate these muscles any further is reinforced by progressively increasing concentric contraction of the anterior muscles until the physiological limit is reached. The reverse movement is of course effected by concentric contraction of the erector spinae[1].

D. *Testing the power of muscles by noting the results of efforts to perform certain movements.*

One frequently finds statements to this effect: "Inability to flex the foot points to paralysis of the anterior tibial muscles, such as is frequently the case in infantile paralysis...." "Inability to extend the wrist and fingers is indicative of paralysis of the extensors on the back of the forearm, as is seen in the wrist drop that results from paralysis of the musculo-spiral nerve...." These remarks might easily be misinterpreted (and they often are) as implying that such inability is a sign of *total* paralysis of the muscles referred to. This is, however, by no means necessarily the case; it merely shows that the muscles concerned are incapable of being concentrically contracted against the resistance to elongation of their antagonists, probably augmented by the pull of gravity which as a rule is never eliminated during the carrying out of such tests. Indeed it may be quite possible that if by means of posture or fixation gravity be first eliminated such concentric contraction may be demonstrable in the apparently totally paralysed muscles. And even if none can be thus obtained one is not justified in pronouncing a verdict of total paralysis until it has been proved that the muscles are quite incapable of excentric contraction. This is tested for by first passively performing the movement which the subject cannot perform unaided and then asking him to resist while the reverse movement (i.e. the return to the original position) is allowed to take place. Any retardation in the same as compared to its rate when the subject makes no such efforts is a proof of excentric contraction in the muscles that cannot as yet contract concentrically[2].

Examples of all the foregoing might be multiplied to an almost indefinite extent, but those that I have given I think are sufficient to show what an important part the pull of gravity plays in movements of joints and how it can modify muscular activity and change concentric into excentric contraction. In conclusion I beg to express the hope that the power of excentric contraction will receive due appreciation and be accorded its correct place in text-books on anatomy, clinical medicine and neurology.

[1] What I have said above might at first sight give the impression that I consider that excentric contraction of muscles only takes place when it becomes necessary to antagonize the power of gravity which would if unopposed induce any given movement. This is of course not the case, as apart from the external agency of gravity, it is well known that the internal agency of concentric muscle contraction can induce it. Every such contraction is invariably accompanied by its antagonist allowing its tonic contraction to be overcome, or in other words by going through excentric regulating relaxation. The degree of excentric contraction in the latter case is however very much smaller than in the former case where the force of gravity has to be counteracted and regulated.

[2] For further details see the author in *Brit. Journ. Child. Dis.* XI. 155–167, 1914.

THE SYMINGTON PRIZE IN ANATOMY

Professor Johnson Symington, M.D., F.R.C.S. (Ed.), LL.D., F.R.S., retired from the Chair of Anatomy in Queen's University, Belfast, in 1917. This is not the place to record the value of Professor Symington's work for Queen's University, it is sufficient to say that it is written in permanent records there; and in some measure was recognised when he was given the honorary degree of LL.D. It was considered, however, among his friends, that a memorial to Professor Symington which would characterise his own work should be founded by the University. A committee was appointed to consider the means to be adopted and instituted the "Symington Memorial Fund." Subscriptions to the fund were soon obtained, many of them, it is a pleasure to note, coming from those in all parts of the kingdom who had been associated with Professor Symington in his work; and it was resolved to found a Prize in Anatomy to be styled "The Symington Prize," the committee believing that this would be a worthy memorial to him and one which would be to his own liking.

The "Symington Prize" in Anatomy of Queen's University of Belfast is now founded. It is the accumulated income of the Symington Memorial Fund. It is to be awarded every three years and for the first award will be of the value of about £30. The nomination to the prize rests with the Council of the Anatomical Society of Great Britain and Ireland and is to be made by the Council, entirely in its discretion, on the published results of research in Anatomy during the preceding three years. The prize is open to all junior anatomists who are members of the Anatomical Society of Great Britain and Ireland; holders of professorial rank are debarred.

It will give great pleasure to those who know him to learn how closely these arrangements agree with Professor Symington's own wishes and how pleased he is that there is in the award of the Society, of which he has been so long an active member, a prize for the encouragement of research among junior anatomists and which it must be so great a distinction to win.

The Prize has been awarded for the first time this year (1923) and the Council have nominated Dr Appleton, Cambridge University, and Dr Blair, Glasgow University, as the holders.

The next award will be made in 1926 when the value of the Prize will be about £40.

REVIEWS

Cunningham's Text-book of Anatomy. Edited by ARTHUR ROBINSON, M.D., F.R.C.S. (Ed.). The Oxford Medical Publications. Henry Frowde and Hodder & Stoughton, London.

Twenty years have elapsed since the first appearance of this well-known text-book and little need be said in commendation of a work whose merits have been so exhaustively tested during that period by thousands of students and teachers all over the world.

"Daniel Johannes Cunningham adhuc loquitur"—this volume could have no more apt introduction, for, however changed the instruments, the vocalisation remains the same.

Naturally, the duties devolving upon the modern contributors are those of emendation and addition; these duties have been most worthily carried out by Professor J. T. Wilson who has re-written the article on the ductless glands, by Professor T. B. Johnston who has amongst other things greatly improved the article on the fasciae of the pelvis, by Professor S. E. Whitnall who has given us some very precise diagrams and especially by Dr E. B. Jamieson whose clear cut diagrams of many of the bones will be very welcome to the student. At the same time Professor T. Elliot Smith has made important alterations in his valuable article on the nervous system, more particularly as regards the cerebellum; while the editor, Professor A. Robinson, has incorporated most of the important results of recent investigation in his article on the development of the vascular system.

These are some of the more outstanding features of the present edition which is, and no higher praise can be bestowed upon it, a worthy successor of its predecessors.

Whatever Cunningham's text-book has to offer it may be said that, like every so-called text-book of anatomy, it fails in its objective since it caters for too wide a circle of readers. It demands the audience of the student, of the teacher and of the practitioner simultaneously. It would fulfil, at one and the same time, the functions of a text-book and of a reference book—candidly, it achieves neither.

Unfortunately anatomy, like every other observational and descriptive science, proceeds from data to generalisation and consequently the *Euclid of Anatomy*—the book which will proceed in logical, orderly and reasoned fashion from generalisations and principles to the facts and conclusions of structure (histological, embryological and macroscopical)—will be forthcoming in the distant future. Meantime many more steps than have been attempted hitherto

could be made toward this laudable ideal, and this to the great advantage of the student in particular—if a little more of the poetry and a little less of the prose of our science were tolerated in our text-books.

R. A. D.

The Anatomy of the Human Orbit and Accessory Organs of Vision. By S. Ernest Whitnall, McGill University. The Oxford Medical Publications: London.

When Professor Whitnall was at Oxford with Professor Arthur Thomson —to whom he inscribes this volume—it fell to his lot to give lectures to candidates for the Oxford Diploma of Ophthalmology, and these lectures afford the basis upon which the book is founded. It is, however, much more than a mere collection of lectures, being in reality a full work of reference on the subject with which it deals. The author has enlarged the scope of his work to include the neighbouring accessory sinuses of the nose and the cerebral connections of the orbital nerves. He has also described exhaustively all the structures lying within the four walls of the bony orbit and outside the eye itself: in fact, the only structure that he appears to have omitted as unworthy of remark would seem to be the *vena centralis posterior.*

The illustrations are numerous and good. One may not be enamoured with photographs as media for portraying dissections of soft parts, but good use is made of them in this book. Perhaps, in future editions, Professor Whitnall may see good to modify one or two of the schemes dealing with motor nerves to the orbit; as they stand they might conceivably afford the ignorant some ground for saying that these nerves in general emerge from the pons.

As stated above, the work is to be regarded as a book of reference, since the author seems to have extracted tribute from nearly everybody who has written anything on the orbit, or its contents, within relatively recent years; further, he has given a most extensive bibliographical list. Yet the book is no dry association of authorities under headings, but a well-written and most interesting series of descriptions of the several subjects of which it treats, and is in every way a volume which should have a recognised place in any anatomical library. The production is of the high standard that we are accustomed to find in the Oxford Medical Publications, and Professor Whitnall and all concerned are to be congratulated on the appearance of the work.

J. E. S. F.

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